SCS
NATIONAL
ENGINEERING
HANDBOOK

SECTION 22

April 1972

SNOW SURVEY
and
WATER SUPPLY FORECASTING

SOIL CONSERVATION SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

The Soil Conservation Service National Engineering Handbook is intended primarily for Soil Conservation Service employees. The handbook covers many phases of engineering in the soil and water conservation program.

Section 22, Snow Survey and Water Supply Forecasting, contains information and procedures for conducting snow surveys and forecasting water supply provided by snow survey supervisors and their staffs. Gregory L. Pearson, hydrologist, Water Supply Forecasting Unit, Soil Conservation Service, Portland, Oreg., prepared the manuscript for this section with the assistance of the following: Manes Barton, A. G. Crook, R. T. Davis, R. W. Enz, P. E. Farnes, T. G. Freeman, W. T. Frost, T. A. George, Paul Keil, R. E. Malsor, D. W. McAndrew, M. W. Nelson, G. W. Peak, W. G. Shannon, H. J. Stockwell, J. N. Washichek, B. L. Whaley, and J. A. Wilson.

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SCS NATIONAL ENGINEERING HANDBOOK

SECTION 22

SNOW SURVEY AND WATER SUPPLY FORECASTING

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SCS NATIONAL ENGINEERING HANDBOOK

SECTION 22

SNOW SURVEY AND WATER SUPPLY FORECASTING

CHAPTER 1. WATER SUPPLY FORECASTING PROGRAM ACTIVITIES

Purpose and Scope

This section of the engineering handbook contains information for Soil Conservation Service (SCS) employees who are responsible for conducting snow surveys, forecasting water supplies, or assisting in these or related activities. It includes all the procedures currently used by SCS in collecting basic data and in preparing and releasing the data and water supply forecasts to water-using groups and the general public.

Data Collection

Any kind of water supply forecast requires the collection of basic data about snow accumulation in the mountains and the amount of rainfall. Secondary data include soil moisture, base flow of streams, soil and air temperatures, humidity, solar radiation, wind movement, bank and channel water losses, and evapotranspiration. Records of stream diversions and reservoir storage are necessary to correct stream gage data so that the data represent natural streamflow conditions.

Snow surveyors use sampling equipment, aerial markers, and snow pressure pillows on or near snow courses to measure snow depth and determine its equivalent water content. The amount of rainfall is measured by precipitation gages. These and other devices that provide forecasting data are discussed in chapters 2 and 3, and their maintenance is discussed in chapter 8.

Travel to obtain data is done in automobiles, oversnow machines, aircraft, and on skis and snowshoes, often on snow-covered roads or over an undisturbed snowpack in cold weather. Snow surveyors are trained to work safely and know how to survive under hazardous snow conditions (see ch. 4).

Forecasting

In the West, winter precipitation occurring as rain or snow comes in storms that extend over a relatively large area compared with summer thunderstorms. Further, data such as snow water equivalent and total precipitation represent a combination of several storms over a season.

tending to reduce local deviations that may occur during individual storms. Seasonal accumulation follows a rather consistent pattern for large areas having comparable elevation and exposure. The amount of accumulation varies seasonally and year by year. These trends permit the use of index procedures for forecasting water supply.

Variations in mountain snowfall in relation to mountain area represented tend to be greater in the southern Rockies, from Wyoming through Colorado, Utah, New Mexico, and Arizona, than along the Cascade and Sierra Ranges of the west coast.

After collecting and recording the data, computer programs assist in correlating the various factors for maximum accuracy in forecasting water supply. The processing and use of the data in the development of forecasts are discussed in chapters 5 and 6.

Reporting

For data and forecasts to be useful, the data release and reporting system must be timely and must satisfy a multitude of needs on a local, state, and regional basis. The information is useful to agricultural interests and to many others such as agencies managing major river reservoir systems. Normally, snow data are furnished directly to many agencies for their use in management planning and operations. Forecasts of streamflow and the general impact on water conditions are provided in formal reports and through general news releases (see ch. 7).

Administration

Snow survey supervisors are concerned directly or indirectly with administrative or management functions such as scheduling workload, purchasing supplies and equipment, cooperating with other agencies and organizations, training snow surveyors, and evaluating the program. These topics are discussed in chapter 9.

CHAPTER 2. DATA COLLECTION FOR WATER SUPPLY FORECASTING

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CHAPTER 2. DATA COLLECTION FOR WATER SUPPLY FORECASTING

A data network provides basic information for preparing water supply forecasts. Procedures for the establishment and operation of a data network are not exact; within any given watershed the factors that affect runoff, water management, probable accuracy of forecasting, and economic benefits expected must be weighed carefully by experienced SCS employees.

Data collection sites are located so that they represent hydrologic and climatic conditions of a substantial area of a watershed. A snow course, for example, may be selected to represent a condition of snow cover and an aspect for an area 1,000 feet higher or lower and extending several miles from another data site.

Because the data are to provide an index for predicting a volume of runoff, it would appear that the more data available, the more accurate the forecast. But there is a practical limit to the data that can be gathered because of physical, financial, and other limitations. The records show that data, gathered at similar elevations and exposures even miles apart, e.g., snow water equivalent, often have a high degree of correlation.

Actually, runoff from snowmelt can be indexed with reasonable accuracy from limited data. The measurement of snow water equivalent from a snow course taken near the time of maximum snow accumulation may provide a good runoff index for a snow-covered watershed of 1,000 square miles. Using two or three measurements of snow water equivalent distributed over the watershed generally increases the accuracy of the runoff estimate. With an increase in the number of snow courses, however, the rate of increase in accuracy decreases rapidly. If data from 10 snow courses are available, the increase in accuracy from adding another snow course is negligible. If all the snow course measurements are considered as independent variables, some coefficients are negative because of intercorrelation. Adding other variables to forecast procedures, such as soil moisture, base flow, or precipitation, is much more likely to increase accuracy. A discussion of the forecasting variables and how they are measured and recorded follows:

Snow Water Equivalent

Snow Courses

A snow course is a selected line of marked length in snow accumulation areas. Its length ranges from about 300 to 1,000 feet or more, depending on site conditions and uniformity of snow cover along the snow course. Sampling points are established along this line at intervals of usually 25, 50, or 100 feet. Any large obstruction on or near the line may require increasing or decreasing the interval for one or more sampling points.

A snow surveyor measures the snow depth and determines the equivalent water content at the same points each time the snow course is scheduled for measurement. The end points of the line are permanently marked, usually by steel pipe set in concrete. Individual sampling points may also be marked to facilitate locating the point each time it is sampled. If not, sampling points are located by measuring from the end marker each time the course is measured.

The number of sampling points usually varies with each snow course, but 15 to 20 sampling points are recommended for a new course. After the record is long enough to permit analysis and reduction in the number of points, about ten sampling points should be selected for a permanent course.

Selecting a Site

Accessibility.--Each watershed has its peculiar forecast requirements and problems. In most places the best snow courses for forecasting purposes are the most difficult to reach because most of the snow zone is not readily accessible. Although the course at the highest elevation in a profile network is usually the best--because it usually correlates seasonal snowmelt runoff better than one at medium or lower elevation--a snow course is of no value unless it can be measured on schedule. Accessibility, therefore, is an essential criterion in site selection. Locations near highways at high elevations are preferred if other requirements can be met. Although oversnow vehicles and aircraft have made access possible to more areas than heretofore, oversnow machines generally are limited to secondary or forest roads and aircraft to areas where they can be landed safely.

Security.--Another factor in selecting a site is security. A snow course should not be placed in a good stand of marketable timber that may be cut or that is close to a major highway that may be enlarged. These and other possible future changes should be considered before a snow course is established. Any major change in ground cover or timber stands due to fire or logging operations will change the snow course measurements and negate the historical record. To protect snow courses, land use permits or easements should be obtained from federal or state agencies and private landowners.

Location.--A snow course must be located in an area free of ponded water resulting from poor drainage. A gently sloping terrain is preferred to a flat area or a steep slope. A flat area may be dry and appear to have good drainage during a summer field inspection, but may prove otherwise under winter conditions. The intrusion of beavers and the building of beaver dams may be a problem. Usually, steep slopes are free of ponded water; snowcreep, however, can bend the snow course markers out of alinement and make readings unreliable. Sampling difficulty increases with slope.

Canopy cover should be considered too. The predominant vegetation in the watershed may be sagebrush, deciduous trees, or a dense stand of conifers. The amount and kind of forest cover directly influences the amount of snow that accumulates at a given site. Snow courses above timberline generally are not satisfactory because of wind. The same problem exists in the open sagebrush areas of the West.

Experience and research have shown that snow courses located in small protected mountain meadows have a minimum of drifting and are generally ideal sites. In Rocky Mountain areas, aspen groves may be satisfactory locations since they do not pose a major interception problem. But they may be affected by wind. Dense forest cover should be avoided. Large cones that form around trees may give unrepresentative measures of snow depth and water equivalent.

For orientation or aspect, a north-facing slope provides the maximum accumulation of snow because winter melt is minimal. Southern or western slopes, except at the highest elevations, should be avoided as well as areas on the lee side of a hill where large amounts of snow may accumulate from drifting. Orographic effect from massive topographical features also must be kept in mind.

Area of Representation.--Since the purpose of a snow course is to provide a representative sample of the snow in a watershed, the elevation, aspect, and other conditions of the course should represent the area that produces the water. An elevation must be selected where there is a minimum of preseason melting. The course should not be so high that the area sampled is too small to represent a major water-producing elevation zone. An area-elevation map of the basin aids materially in determining this point.

Water supply forecasts based solely on snow courses at high elevation may prove to be in error because of an excess or deficiency of snow cover at low elevation. In some places, courses at low elevation are needed to indicate midwinter snowmelt or early runoff. A snow course at an elevation and aspect that is usually bare of snow when the information is needed for forecasting is of little value.

Snow Course Profiles

Because snow accumulation and total precipitation can vary substantially with elevation and aspect, several stations are usually located along a route to the highest snow course. Measuring these additional courses or stations takes little more field time and expense and generally improves runoff indexes. Typically, the elevation difference between snow courses in a profile is 500 to 1,000 feet.

Network density should be determined on a profile or route-of-measurement basis rather than by individual stations. In general, for large watersheds, snow courses in a profile over a mountain range need not be less than 10 air miles apart with 40 to 50 miles as the maximum distance. The profiles are usually 20 to 30 miles apart.

Marking, Mapping, and Recording

When a satisfactory location has been found, the snow course and the trail to it should be marked, mapped, and recorded to make them easy to locate under adverse winter conditions and deep snow. Standard markers (fig. 2-1) should extend above the deepest snow. End points and angle points should be marked with a steel pipe of 2-inch or larger diameter set in concrete. Standard snow course markers should be bolted securely to the top of the pipes and the pipes painted orange or red and yellow. Individual sampling points are often marked with numbered metal tags nailed to trees near the sampling point or to wood or metal poles set at the points as indicated. This method insures accurate location of sampling points and is convenient for surveyors.

A typical map is shown in figure 2-2. Its three separate parts--site map, route map, and plot of sampling points--should be included in a snow course map to show the surveyors the sampling spacing and course layout and to indicate the general route from a well-defined point to the snow course, and the relation of the snow course to the drainage pattern. All maps should have the standard map heading and title block.

Pertinent data are recorded on a snow course biography form (fig. 2-3) at the same time the course is mapped and marked. The completed form is kept in the snow survey supervisor's office.

Snow Sampling Equipment

The federal snow sampler tubing is made of duraluminum. Its outside diameter is 1-3/4 inches, and its inside diameter is 1-11/16 inches. It is made in sections 30 inches long, and each section is marked at 1/2 inch intervals. The first, or lower section, has a steel cutter bit that is cold shrunk to fit the heated lower end of the section. The cutter bit has an inside diameter of 1.485 inches, which is about three-sixteenths of an inch smaller than the inside diameter of the tubing. This difference permits easier sampling and removal of the snow core. The tube sections are assembled by threaded couplings to lengths of 300 inches or more. The slots spaced alternately along the tube sections are provided for observing the length of core. Snow water equivalent is determined by weighing the tube and its snow content on a tubular spring scale. The weighing cradle that holds the snow tube is attached to a spring clip on the bottom of the tubular scales. The scales are in three sizes; i.e., for snow depths of 12.5 feet, 20 feet, and 30 feet. All scales weigh in ounces. Since the cutter point of the sampler cuts a snow core 1.485 inches in diameter, each ounce of core is equivalent to 1 inch of water.

Spanner wrenches are used to unscrew the sections that may tighten in place when sampling. The driving wrench is clamped on the tube to drive it into deep, hard, compact snow and to cut through layers of ice. Standard snow sampling equipment is shown in figures 2-4, 2-5, and 2-6. Specifications are available from the SCS Water Supply Forecasting Unit (WSFU). Figure 2-7 shows the sampling tubes and other pertinent items usually included in a snow sampling set.

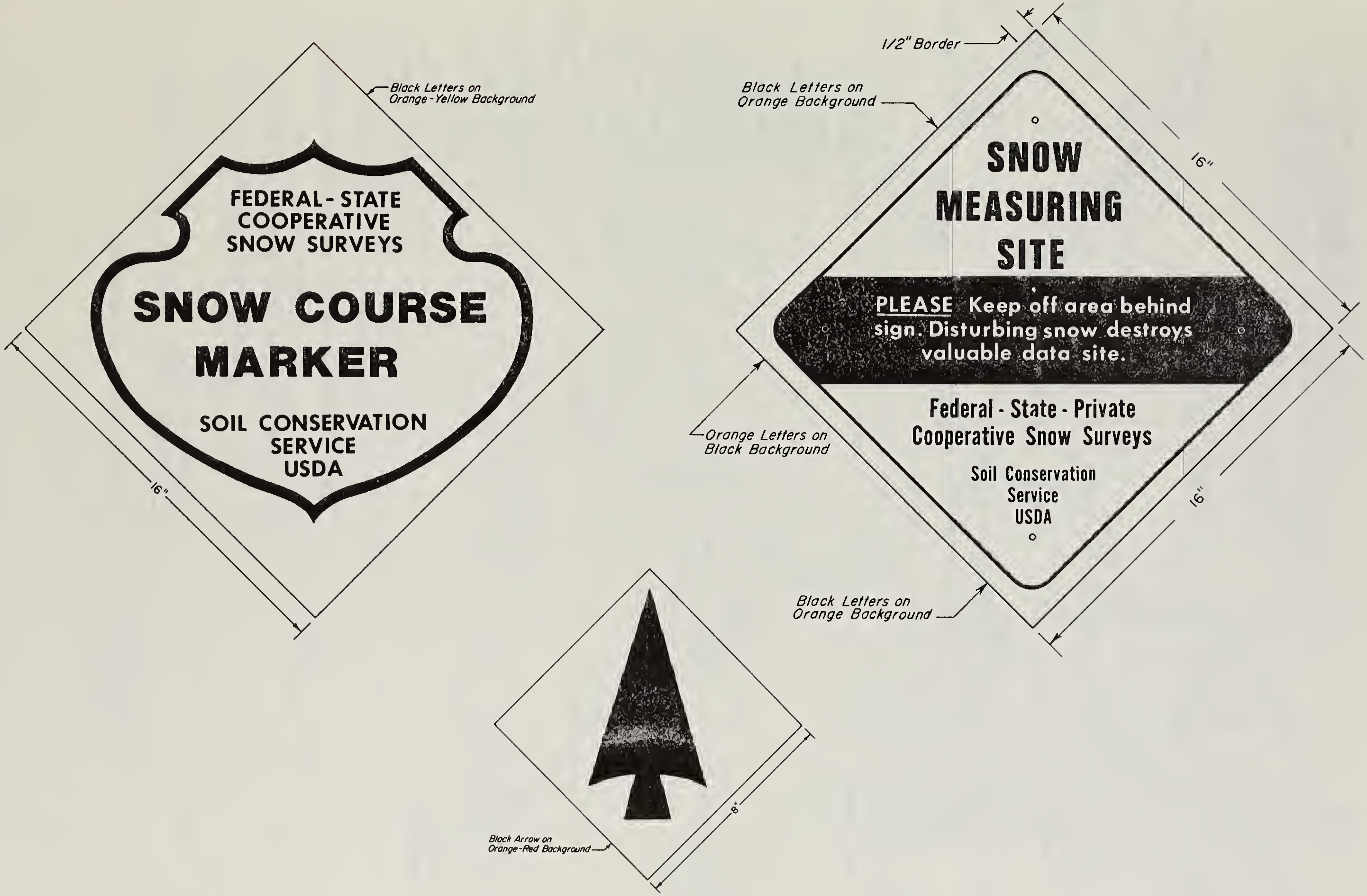


Figure 2-1.--Snow course marker, trail marker, and snow measuring site warning signs, constructed of 1/4-inch or 3/8-inch Masonite or hardboard.

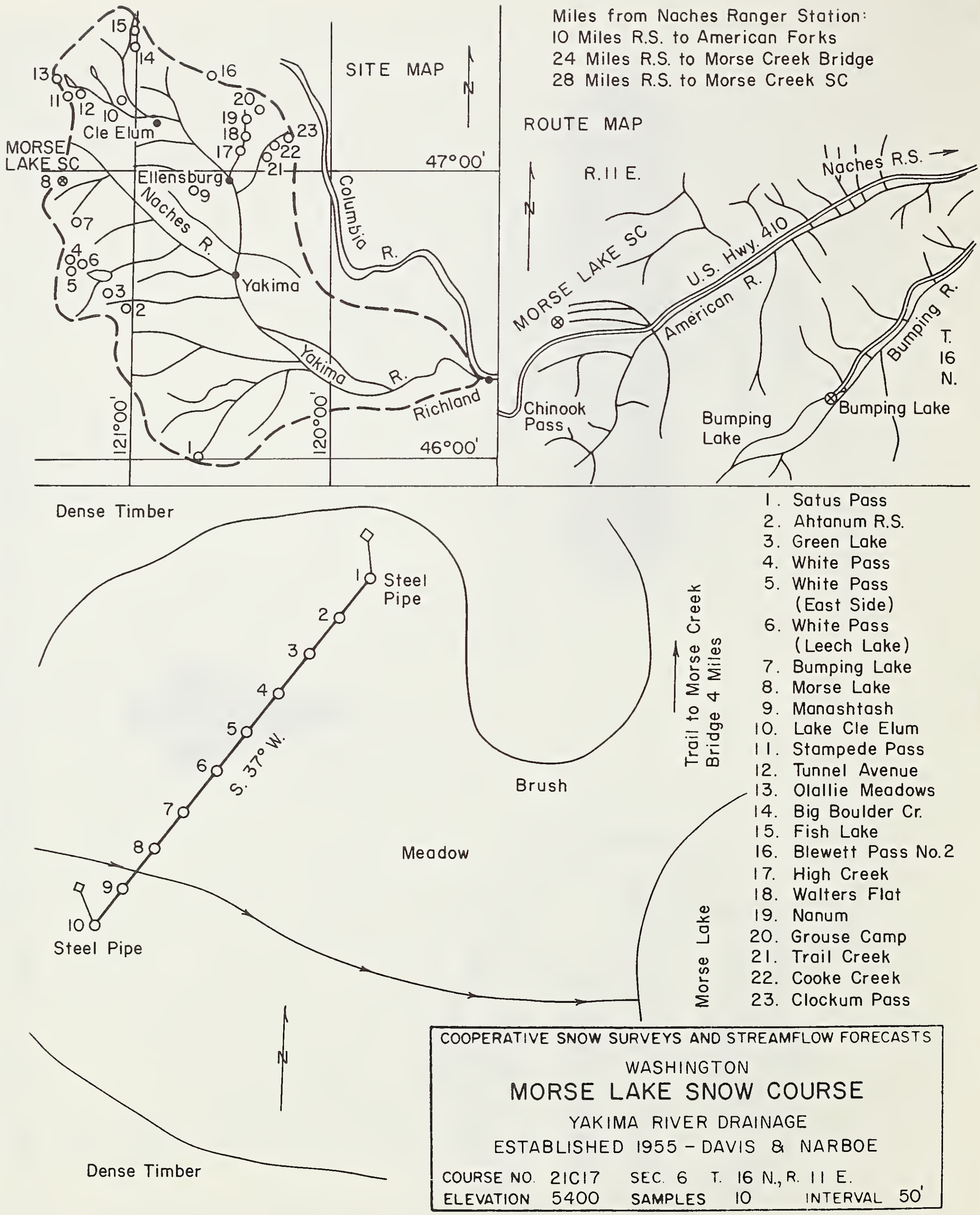


Figure 2-2.--Typical snow course map.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SNOW COURSE BIOGRAPHY

Nevada
(State)

Name Marlette Lake Number 19K4M

Location: Sec. 13 Twp. 15N Range 18E Base and Meridian Mt. Diablo

Lat. 39° 09′ Long. 119° 53′ Elevation 8000 ft.

Basin Great Major Drainage Lake Tahoe Local Marlette Lake (bypassed into Carson River)

Aspect(facing) North Exposure(include base vegetation) open Aspen

Route to Snow Course: On road into caretaker's house at Marlette Lake; 100 yards from lake. See snow course map.

Method of Travel: Oversnow machine

Round trip miles snow travel per measurement 10

Measurement Schedule: Snow Course on Feb. 1, March 1, April 1. Telemetered snow pillow hourly on automatic interrogation, or manually as desired.

Read by: SCS - Truckee Forecast Committee

Financial Support Agency: SCS - T.F.C.

History:

Established in 1915 by J.E. Church. Course revised in 1947 to 11 samples at 25 feet. Straight line course. Marked with steel pipe set in concrete in 1947. Snow pillow installed in fall 1966.

Land Owner: State of Nevada

General Comments and Recommendations:

Good course for forecasting Lake Tahoe and Truckee River. Marlette Lake major source of Carson City and Virginia City domestic water supply.
Needs cleaning about every 5 years.

Manes Barton

10/15/64
Date

Figure 2-3.--Snow course biography form.

462-302 O - 72 - 2

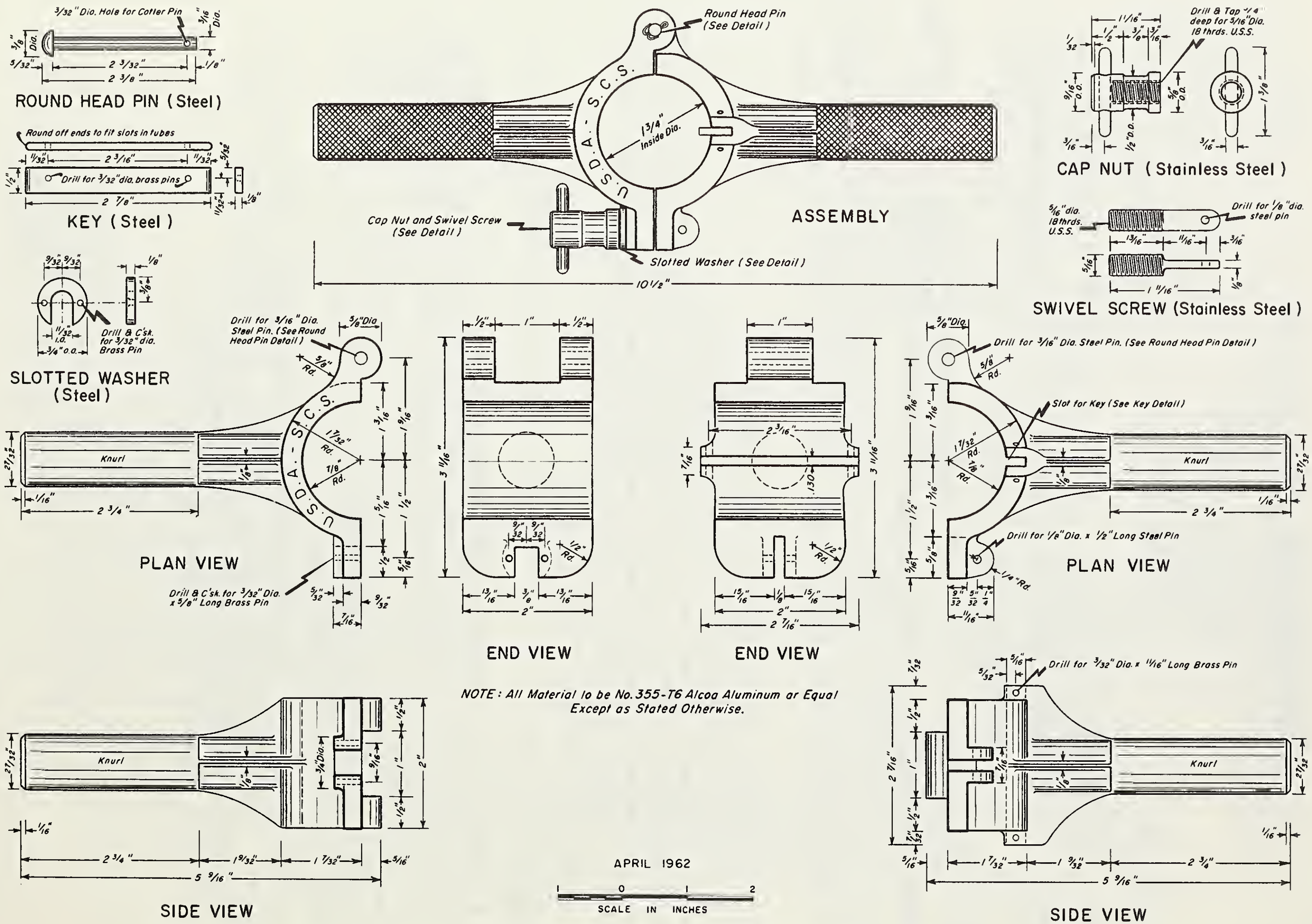


Figure 2-4.--Driving wrench for federal snow sampler.

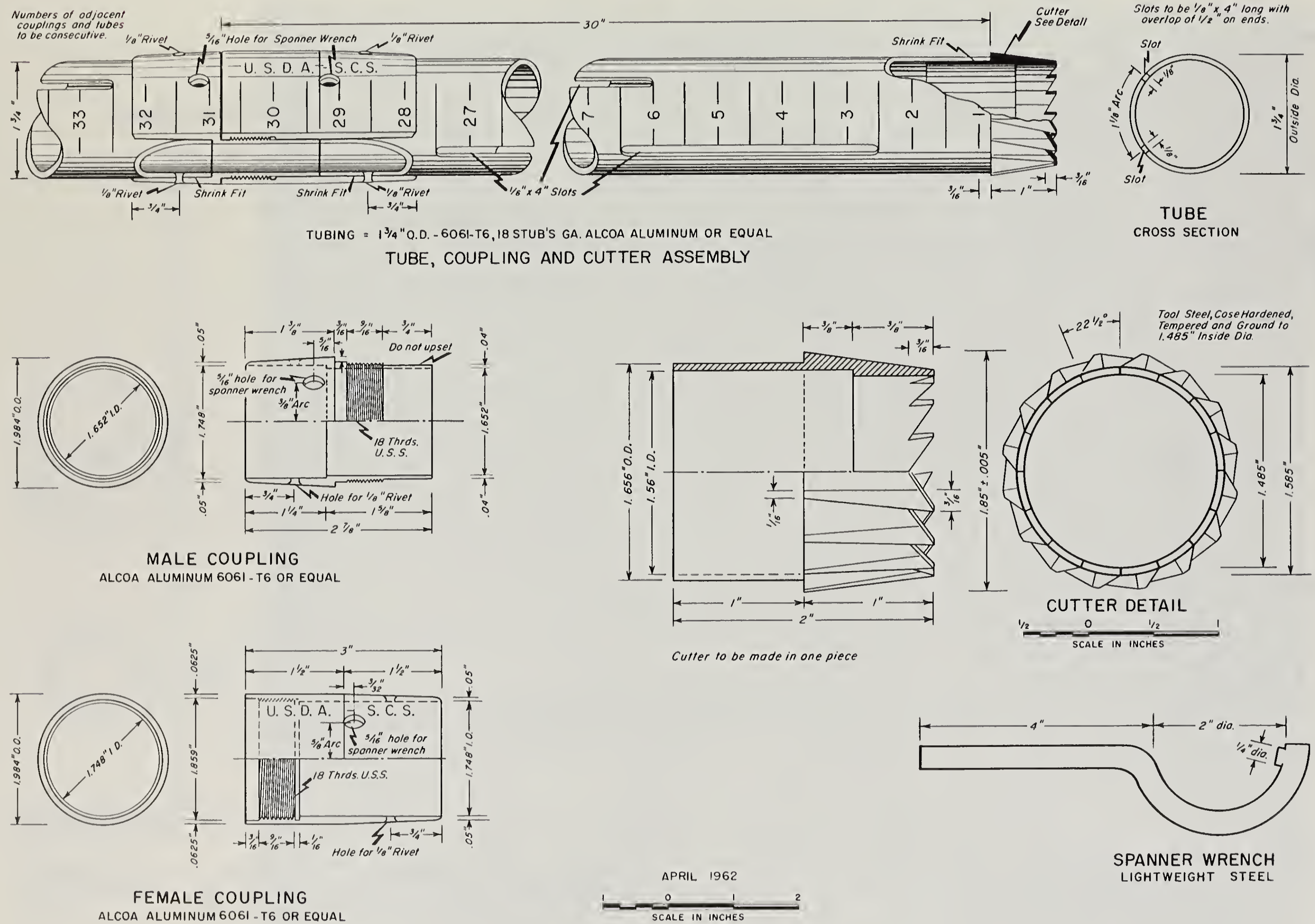


Figure 2-5.--Cutter, tube, couplings, and spanner wrench for federal snow sampler.

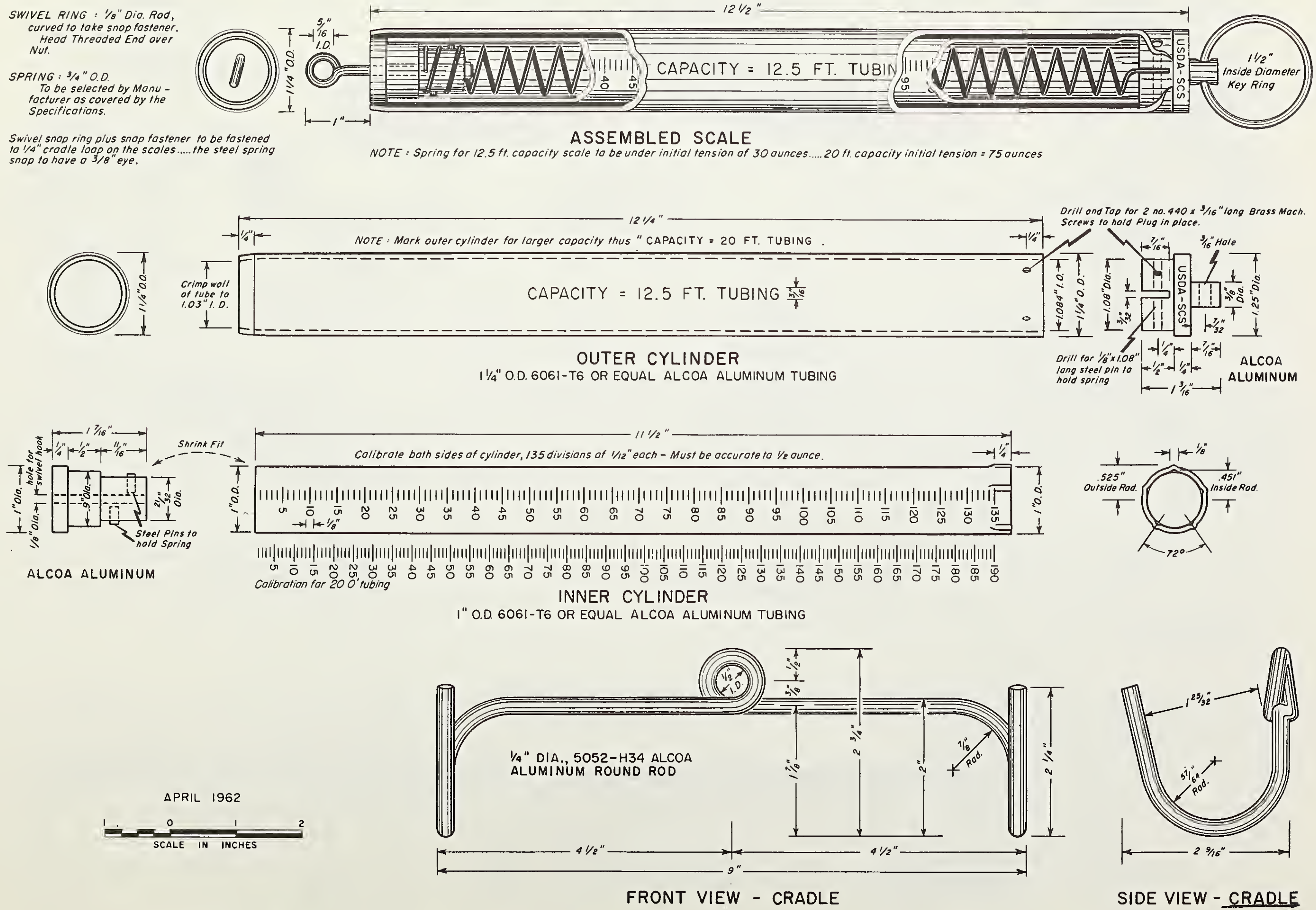


Figure 2-6.--Weighing scale and cradle for federal snow sampler.

Figure 2-7.--Snow sampling set and related items.

Snow Survey Procedure

The Snow-Survey Sampling Guide, Agriculture Handbook No. 169, gives detailed steps and illustrations of sampling procedure and recording of snow survey notes. This handbook is a part of the snow sampling kit.

Driving the Tube.--Avoid plunging the tube. A steady downthrust is preferable to twisting. But a minimum amount of twisting aids in driving and also facilitates quick cutting of the thinner ice crusts. If the sampler sticks or freezes in the snow, a slight twisting usually releases it. If the driving wrench is needed, fasten it 1 or 2 feet above the surface of the snow to prevent bending of the tube. Engage the key on the inside of the wrench completely in one of the slots and fasten the clamp screw securely (see fig. 2-8).

Snow temperatures below 32° F. and air temperatures above 32° F. often cause snow to adhere firmly to the cutter orifice. This difficulty generally can be overcome in one of several ways:

1. Withdraw the sampler if the cutter becomes clogged and clean the cutter and outside of the tube thoroughly. Select a new sample point a few inches away. Push the tube rapidly through the snow without stopping until the bottom is reached. Repeat this procedure until a complete core is obtained.
2. If sampling in a forest, keep the sampler in the shade and lay it in snow between measurements to keep it as cold as possible. If sampling in the open, keep the snow core in the tube while walking from one sampling point to the next, sliding the core back and forth in the tube to keep it cold. Walk in the shade as much as possible.
3. If possible, sample when the air temperature is below freezing.
4. Keep the tube waxed and polished.
5. If possible, take samples in the morning or evening and not during the warm part of the day.
6. To obtain samples under the most adverse conditions (cold deep snow and warm day), thrust the tube as deeply as possible without stopping. At the first sign of resistance, withdraw the tube. Record the core length and weight. Dump the core and return the empty tube carefully to the bottom of the partial hole. Then apply full steady pressure to force the tube deeper and, if possible, to the ground surface. Withdraw the tube and record the core length and weight. This procedure may have to be repeated to reach ground surface.

After the core has been dislodged, the inside of the tube usually still has snow adhering to the sides. Sometimes this extra snow can be removed by rapidly taking several more samples and throwing them away. It is often necessary to draw a cloth tied to a strong cord through the tube to remove the snow. Wear heavy gloves when sampling. If thin gloves or bare hands are used on the sampling tube, the heat of the hands warms the tube, causing the snow to stick at these points.

NEV-858

Figure 2-8.--Snow surveyors driving in sampling tube.

Under adverse conditions it may take two skilled snow surveyors as long as 5 hours to take 10 samples. A full explanation of all problems should be recorded in the notes to help the snow survey supervisor to interpret notes properly and to allow him to plan a better sampling arrangement if necessary.

Weighing the Sample.--When the sample has been taken, place the tube in the cradle attached to the scales and record the weight of the tube and core to the nearest one-half inch. Remove the tube from the cradle and expel the snow core. Place the empty tube in the cradle and record its weight to the nearest one-half inch. Recheck the weight of the empty tube every three or four samples.

Never grasp the barrel of the scales in weighing the tube. This causes the graduated cylinder to bind on the sides, and the weight will be incorrect. Hang the scales from a strap through the ring on a ski pole or on a staff or from a cord around the assistant's neck. The scales must hang free like a pendulum. Use no oil or grease on any part of the scales. To keep them from sticking, tap the scales lightly.

Removing Dirt.--Clean any dirt from the cutter before weighing the sample. Subtract the length of this dirt core before recording the length of the snow core and depth of snow. Throw the dirt well off the course to prevent formation of snow pits caused by increased melting around the dirt.

Recording Field Data.--Aluminum notebook holders are provided to protect field notes. Sketch maps of courses are attached to the inside cover. Use a pencil (not ink) to record field measurements. While in the field, complete the top section of the field note, form SCS-ENG-708 (rev. 3-70), for every sheet and for the reverse side in the snow survey notebook. Figure 2-9 shows a completed set of field notes.

Snow Depth and Core Length.--Read and record snow depth to the nearest inch. The length of core is usually less and never more than the depth of snow. Determine any deviations and note them under "Remarks." The core length should be no less than 90 percent of the snow depth, except in extremely light or soft snow. Read and record the core length to the nearest inch.

Density.--The density of each sample can be determined by dividing water content by snow depth. The density determination chart found in the green instruction pages in the snow survey notebook facilitates the computation of density in the field. Determine density for each sampling point before leaving the course. Any deviation of more than 5 percent ± in density requires resampling to determine sample accuracy or an explanation under "Remarks," or both.

Remarks.--Use the "Remarks" column for recording soil condition beneath the snowpack and for explaining any irregularities in an individual snow sample. On the other side of the form, also to be completed, is a checklist that provides space for information on snowpack and soil conditions not otherwise reported.

SCS-ENG-708
(rev. 3-70) UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FEDERAL AND STATE
COOPERATIVE SNOW SURVEYS

State Washington
Drainage Basin Chelan
Snow Course Morse Lake
Party Jones – Smith
Date 4/1/66

*Description or Number of Course	†Sample Number	Depth of Snow Inches	Length of Core Inches	Weight of Empty Tube	Weight of Tube and Core	Water Content Inches	Density Percent	Remarks (See reverse)
	1	151	140	67	125	58	38	
	2	162	128		122	~~55~~	34	59 RTD
	3	160	150		129	62	39	
	4	158	150		129	62	39	
	5	165	131		123	~~56~~	34	61 RTD
	6	165	152	67	128	61	37	
	7	168	157		130	63	38	
RTD	~~8~~	~~170~~	~~115~~		~~121~~	~~54~~	~~32~~	Sampled
RTD	~~9~~	~~172~~	~~121~~		~~122~~	~~55~~	~~32~~	Twice
	10	160	145	67	129	62	39	
Total		1631		670	1258	588		
Avg.		163				58.8		
	8A	169	125	67	121	~~54~~	32	63 RTD
	9A	171	150	67	132	65	38	
Corr. Total		1629				616		
Avg.		163				61.6		RTD

*Show number or description as given on sketch map, *i. e.*, "Course No. 1," or "Major Course," or "N 5° E," etc.

†Always start measurements for sampling from the *initial* point as shown by the sketch map of the course and follow the spacing for samples as indicated. Particular care should be taken to note any *irregular* spacing between samples.

No. 1 of 1 sheets. Comp. by BAJ Checked by CNS

NOTE.—Please fill in while in the field.

DATE OF SURVEY: Began 1:00 ~~a.m.~~ p.m. Ended 2:15 ~~a.m.~~ p.m.

SAMPLING CONDITIONS

(Please check items descriptive of present conditions.)

Weather at Time of Sampling

...... Clear, ... Partly cloudy, ✓ Overcast, ... Raining, ✓ Snowing, ... Blowing, ✓ Freezing, ... Thawing.

Snow Conditions at Snow Course

Snow samples obtained with ...... ease, ✓ moderate difficulty.*
Snow samples obtained with ...... extreme difficulty.*
Ground under snow: ...... frozen, ✓ not frozen, ... dry, ... damp, ✓ wet (saturated).
Ice layer on ground ...... How thick? ...... inches.

General Snow Conditions

1. What elevation is snow line generally? 2500 ft.
2. Is snow melting on north and east slopes? No
3. Is snow melting on south and west slopes? No
4. How many inches of new snow at snow course? 18 in.
5. Is there evidence of snowslides? No

General Stream-Flow Conditions

1. Are very small streams running? Yes ...... No ✓
2. Are small streams bridged over by snow? Yes ✓ No ......
3. Are streams clear or muddy? (*Check one*) Clear ✓ Muddy ......

*Explain fully under remarks.

PRECIPITATION DATA

Month	Day	Year	Precipitation	Readings		Dipstick	Weight
			Current		Made by (check)		
			Previous				
Station name			Catch, inches		Scale number		
			After recharge				

REMARKS: Hard corky layer about 3 feet above ground. Tube tended to plug.

Snow Survey Supervisor adjusted readings 2, 5, 8 and used 9A instead of 9.

U.S. GOVERNMENT PRINTING OFFICE : 1962 O—645907

Figure 2-9.--Completed field notes.

Disposition of Notes at Field and Office Locations

Before transmitting snow survey data to his supervisor, the snow surveyor rechecks the notes for legibility, completeness, remarks, and arithmetic, and initials the "Computed by__________" space at the bottom of the form. The original of the 4-1/4-inch by 7-inch white field note is mailed in time to reach the snow survey supervisor no later than the deadline. Occasionally, weather or some other condition may cause a delay beyond the scheduled date, and a surveyor must decide whether he should mail, telegraph, or telephone the data to the supervisor's office. In any event, the original notes should be mailed as early as possible and must be retained in the files of the snow survey supervisor. A copy of the field notes must be kept in a surveyor's files until the close of the survey season.

Telegrams giving delayed data must contain the following information:

1. Name of snow course.
2. Date of survey.
3. Average snow depth.
4. Average water content.
5. Condition of soil beneath the snowpack.

An employee in the snow survey supervisor's office rechecks all notes received for arithmetical accuracy and continuity of individual samples and, when satisfied, initials them. The results are then posted to the report mockups and elsewhere in accordance with office procedure, and the notes are filed by snow course in chronological order for later reference and microfilming.

Accuracy of Snow Sampling Equipment

In June 1964 the water supply forecasting unit in Portland, Oreg., prepared and issued a report, "Accuracy of Field Snow Surveys in Western United States." The summary and conclusions follow:

> The popular federal snow sampler overmeasures the water equivalent of snow. The error ranges from an average of about 7 percent in shallow, light-density Alaskan snow to as much as 12 percent in deep snow of higher density. This fact might become significant to stream forecasters who use quantitative forecast methods based on federal snow sampler results. The fact is not significant in a forecast system that uses snow cover as an index to resultant runoff. The observation, however, can be singularly important in field studies of other devices to measure snow water equivalent, such as pressure pillows or a radioactive isotope gage, where results from federal samplers have been usually accepted as representing more or less exactly the water equivalent of the snow sample.
>
> It appears that the overmeasurement of snow water equivalent by federal-type samplers (cutter I.D. of 1.485 inches) is related to the shape and arrangement of the cutting teeth. Blunt tooth cutters show the greatest plus error (federal versus Bowman, for instance).

It seems likely that a cutter for the highly portable federal-type sampler could be designed to reduce or eliminate the plus error and yet retain the present cutter's proven ability to cut and hold cores and penetrate dense snow of great depth.

Widely differing air temperatures are shown to offer no appreciable source for error in federal snow sampler scales. The scales themselves are individually accurate at room temperature. The studies show no source of appreciable error attributed to erratic inner cutter-point diameter, although there remains the theoretical possibility that snow-tube accuracy might be, in part, an inverse function of cutter diameter.

Experienced snow surveyors can closely read the tubular scales more consistently than inexperienced surveyors. This effect on accuracy is minor except in very shallow snow.

No evidence was found that slots in the tubes were a contributing source to overmeasurement of water equivalent by federal samplers.

Of the samplers capable of deep snow testing, the Rosen tube consistently demonstrated the least overmeasurement. This is believed to be due to the shape and sharpness of its cutter. The Rosen tube unquestionably is the easiest to drive in deep dense snow, but it does not release snow cores nearly as well as samplers provided by other manufacturers. If the Rosen tube had increased clearance between the cores and the tube barrel inner-face, it would probably be a superior snow sampler. However, since this sampler weighs twice as much as a federal sampler, its use would not be popular if it had to be carried on long foot trips.

The Adirondack sampler is also accurate. However, for snow more than 5 feet deep it is not considered practical under field conditions. If the length were greater than 5 feet and the diameter the same as at present, it would be extremely difficult to drive into dense frozen snow and unhandy to transport on foot. It does not retain its cores well when withdrawn from the snowpack.

The Bowman sampler is accurate and appears reasonably useful for field snow survey work where snow depths are as much as 8 feet.

In general, the present federal snow sampler equipment is about as utilitarian as can be found for deep dense western snows and even for shallow sub-Arctic snow. Design modifications on the cutter point and maintenance of a sharp edge can provide accurate sampling.

Aerial Markers

Use of Markers

Observations of aerial markers are satisfactory substitutes for ground measurements of snow depth and water equivalent during midwinter and early spring. Any lack of precision from using air-observed snow depth and estimated water equivalent instead of ground measurements is offset by seasonal variation in snowfall at later dates. In emergencies, observations from the air can be substituted at or near the time of maximum snow accumulation for measurements otherwise difficult to obtain.

Using air markers avoids the difficulties of oversnow transportation and the hazards of travel in remote regions to obtain many ground measurements. These difficulties and hazards are greatest during the early and midwinter snow accumulation period when cold temperatures, deep powder snow, and avalanches are most prevalent. A number of aerial markers can be observed in the time required for one ground measurement.

During the snowmelt season, when high water, mud, and soft snow may make ground transportation difficult, markers provide a means of checking frequently on the remaining snowpack. These checks are required for short-term forecasts of streamflow for flood control and multiple-purpose reservoir operations.

Site Selection

Aerial markers are used at the remote locations in the mountains, which are most difficult to reach by other means. The criteria for selecting sites for markers are identical to those for snow courses; both are designed to obtain the same data. In addition to the general requirements for snow courses, the markers must be in a position to be observed readily from the air without undue hazard. Markers are difficult to observe among scattered trees and impossible to observe in heavy timber. A minimum distance of 25 feet from any tree and 100 feet of clear area for 90 degrees around the marker are required (see fig. 2-10).

Classes of Markers

The three general classes of marker installations are:

1. Markers at or near a sampling point on a snow course that has a long record of ground measurements. The marker is a direct substitute for a ground measurement of snow depth. The record of ground measurements at this point has been consistently within 4 inches of snow depth and 1 inch of water equivalent of the average for the snow course. Therefore, the depth observed can be considered the depth that would have been observed for the snow course average.
2. Markers near the snow course but removed from the sampling points because of observation requirements (generally to a nearby open space). Installation of a marker at these points requires at least 10 concurrent measurements of the snow course and the marker over a minimum period of 3 years to establish a ratio between snow depth at the marker and that on the snow course. Place the marker where depth and snow density are directly related to the snow course.

Aa-272

Figure 2-10.--Aerial marker.

3. Markers where there is no existing snow course. These markers are located on what would be a good site for a snow course except for remoteness.

Each of these three types of markers requires a somewhat different method for estimating the snow water equivalent.

Estimation of Snow Water Equivalent

The density of snow at an aerial marker located at a point on a snow course is determined by comparing the density of that course with the density of another course that has a concurrent record of ground measurements on nearly the same dates (sampling dates over a 6- to 8-day period). The snow course selected should be as comparable as possible

in elevation, aspect, exposure, snow depth, and density. Ten or more satisfactory comparable density measurements are required.

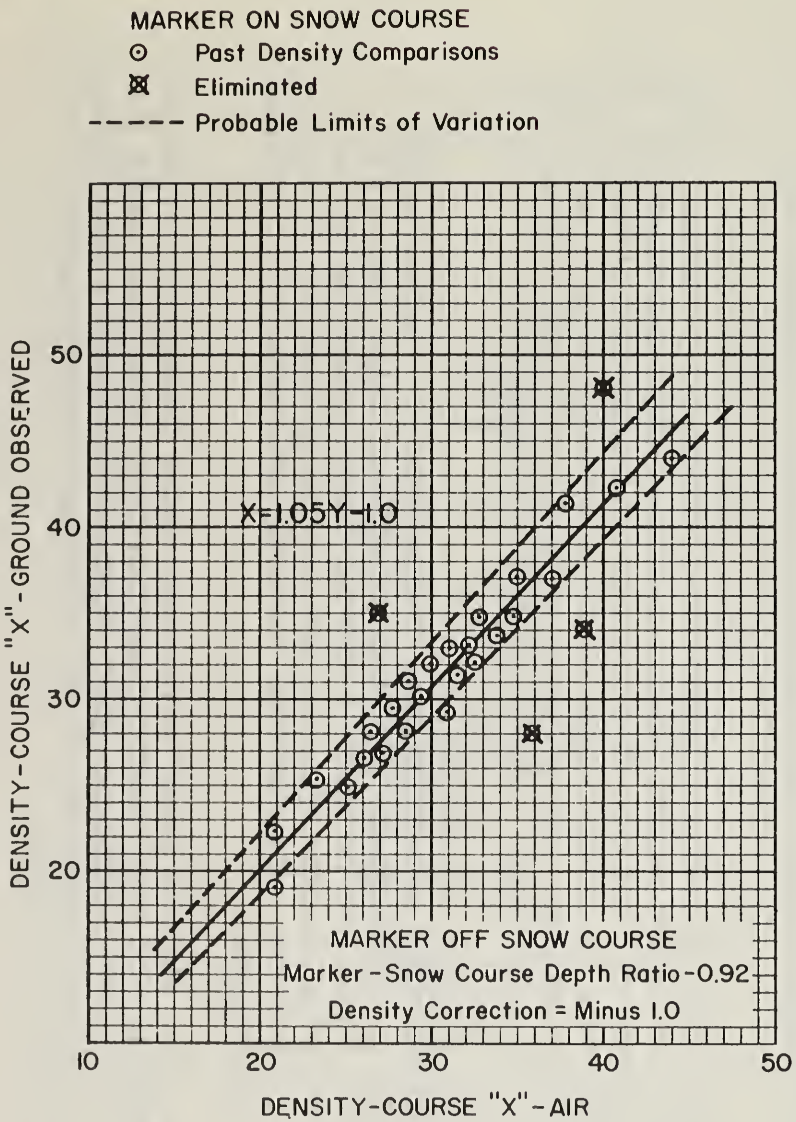
Figure 2-11 is a typical chart used in computing density at a marker by comparing the density at one snow course with that at the snow course at which the marker is located. Note the comparable densities that were eliminated. In comparing density between snow courses, usually about 10 percent of the comparisons vary too much from the others. The reason is related most likely to storms that occurred between the time the two snow courses were measured or to a sampling error or some difficulty in sampling one of the courses. Since this is difficult to check years later, these out-of-line comparisons are not used in calculating the least square line and in establishing the graphic comparison. As a guide, density readings varying more than 5 percent from comparable readings are eliminated.

Using observations made on the same day, the density for the air-observed course is obtained directly from the chart by using the density obtained for the ground-measured course. If there have been 3 days or more between observations, some judgment is required to estimate density. Should storms occur during the period, the density for the air-observed course may need to be increased slightly if the aerial marker is measured last and decreased if it is measured first. A maximum of 3-percent variation in density from the least square line is appropriate unless snowfall between the times of the air and ground measurements has been significant. To estimate the snow water equivalent, multiply density in percent by the observed snow depth.

The procedure for estimating snow water equivalent for a snow course from an aerial marker located near the course is similar to that for a marker located on a specific sampling point. Snow depth as measured on the snow course must be compared with the aerial marker for some time to establish a relationship. If the marker is in the open and the snow course is in heavy timber, a decrease in density of 1 or 2 percent is reasonable. Note the ratio of snow depth at the aerial marker to that on the snow course shown in figure 2-11.

For markers not related to an existing snow course, it is best to assume a density that has been observed on the ground-measured course most comparable in elevation, exposure, aspect, and snow depth. If possible, the selected snow course should be within 25 air miles. Another course may be used if the following factors are adjusted:

> Snowpack decreases in density 1 to 2 percent for each 1,000-foot increase in elevation.
>
> If 100 inches of snow depth are considered as standard, density increases about 1 percent for each additional 10 inches of snow depth and decreases about 1 percent for each 10 inches of snow less than 100 inches.



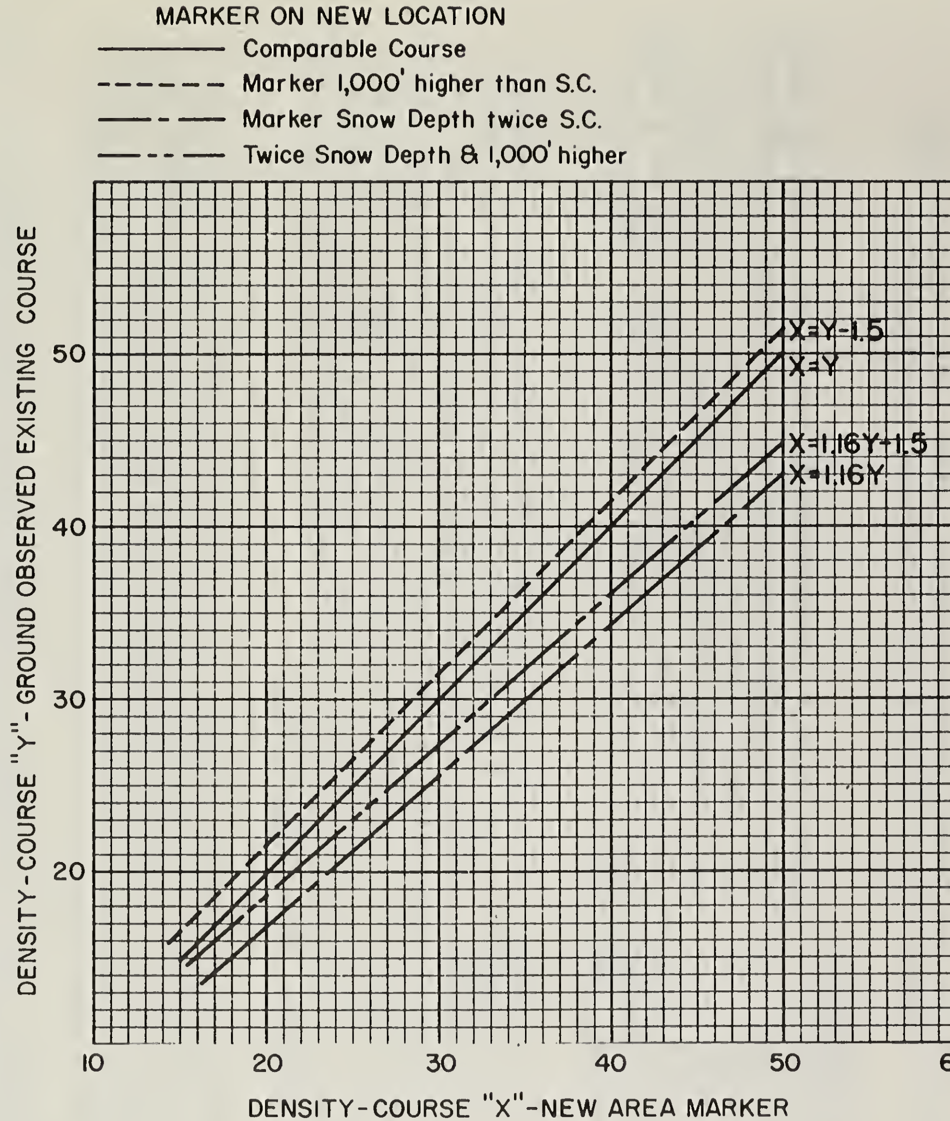


Figure 2-11.--Chart for computing density and water content by comparison with another snow course.

Density is 1 to 3 percent greater in open areas than that on snow courses in timber. Figure 2-11 illustrates these adjustments.

Design of Markers

Aerial snow depth markers have a common design, but the materials used and the dimensions vary. The markers consist of a vertical support or post to which crossbars are attached at predetermined intervals. The post is usually a 2-inch wrought-iron pipe, although a 4- by 4-inch treated post is preferable for areas in which permafrost may be a problem, as in Alaska. Pipes of larger diameter are desirable where snow depth exceeds 150 inches.

Horizontal crossbars are made of wood or sheet metal (about 16-gage). If of wood, dimensions are 1 inch thick by 6 inches wide by 24 to 36 inches long. Width and length are the same for sheet metal. They are placed at 2-foot intervals on the pipe. A 1- by 3-inch wide wood or sheet-metal diagonal is placed between the outside edges of the horizontal crossbars for bracing. Diagonals cross the pipe midway between crossbars. An alternative design has 2- by 12-inch horizontal bars in lieu of diagonal bars (fig. 2-12).

The vertical post should be made in 4- to 6-foot sections. Couplings are used to connect sections. The cross pieces should be designed so that they can be bolted to the support post with 3/8-inch bolts. This arrangement facilitates transport to field locations and replacement of damaged cross pieces.

The preferred paint for markers is bright orange enamel similar to that used for highway signs; these markers should be repainted every 3 to 5 years.

The support post is set in concrete to a minimum of 36 inches or one-fourth of the marker height. On installation, the total height of the marker is recorded and placed with other information on the snow course biography form. The total height of the marker should be 3 or 4 feet more than the maximum expected snow depth. If the marker is too long, counting extra crossbars increases chance of error.

Flying Limitations and Techniques

Weather often makes obtaining data from a network of aerial markers difficult. It is necessary to fly in relatively light aircraft for maximum safety and to be able to observe the markers from the air. In areas and during seasons where clouds and fog prevail for 50 percent or more of the time, air-observed networks are impractical or have severe limitations.

Both the pilot and the observer must use sound judgment for a successful operation. The best safety precaution is to turn back during a flight if weather conditions (gusty winds or downdrafts) place unusual strain on aircraft performance. The pilot must be experienced in flying over mountainous terrain.

SCS-166 Rev.
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FEDERAL - STATE - PRIVATE

COOPERATIVE SNOW SURVEYS

FOR OBSERVERS USE

State *Idaho*
Drainage Basin *Boise*
Aerial Marker *Trinity Mt.*
Observer(s) *Jones*
Wilson
Date *Feb. 27, 1966*

Place a check (✓) on Diagram beside lowest visible <u>wide</u> cross bar
Place a check (✓) beside the next lower <u>narrow</u> cross bar if visible above snow line
Draw line across marker diagram to show snow level
Estimated distance in inches between snow line and <u>bottom</u> of lowest visible cross bar *3*

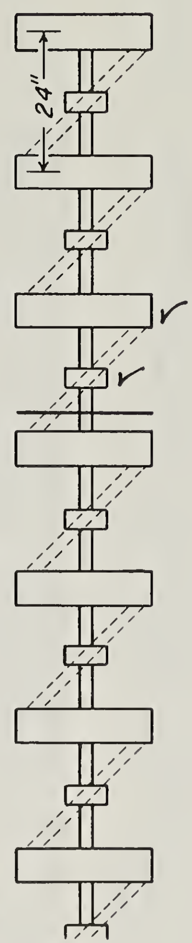
Flying Conditions:
Smooth ✓ Fair ___ Rough ___

Visibility at Marker:
Good ___ Fair ✓ Poor ___

Weather: Cloudy ✓ Fair ___
Cold ___ Warm ✓ Windy ___

Time: *11* A.M. ~~P.M.~~

Remarks *Light Fog in marker Area*



FOR OFFICE USE

Aerial Marker *Trinity Mt.*

Date *Feb. 27, 1966*

Marker Height (Inches) *172*

Obs. Snow Depth *105*

Conversion Formula

Corr. Snow Depth

Reference Snow Course *97*

Density *103*

Density Formula *TM = 98 BB - 2.0*

Computed Density *29.8*

Water Content (Inches) *30.9*

Remarks

Computed by *JAW.*

Checked by *MWN.*

Figure 2-12.--Air marker diagram and typical field notes.

462-302 O - 72 - 3

The aircraft must have adequate power and lift characteristics for operating in the mountains and must be capable of maintaining safe flight for short periods at speeds of 40 to 60 miles per hour. For safety, the plane should be serviced for flying at least four times the amount of time anticipated for an observation trip. Contracts should be based on air miles of travel rather than on a per observation basis.

Flights over markers should be made from uphill to downhill to provide space for additional maneuvering after an observation is made. The flight is made slightly to one side of the marker and approximately parallel to the crossbars. Two passes should be made to insure accuracy of observation in counting the number of crossbars. Photographs are not required.

Observations are generally made from heights of 300 to 500 feet above the marker and to 1,000 feet under good conditions. Under all conditions and particularly for fair or poor visibility, flying any lower than 300 feet above the ground should be avoided.

Recording Field Observations

Snow depth information is recorded on form SCS-166(rev.), (fig. 2-12). An aerial observer counts the cross pieces on the marker, draws a line across the diagram showing the snow level, and estimates the distance in inches between the snow level and the bottom of the lowest crossbar. The observer also notes on the form other pertinent information as to flying conditions, visibility at the marker, weather, and time of observation.

Snow depth is determined by subtracting the distance from the snowline to the top of the marker from the total marker height. Snow water equivalent is calculated by multiplying snow depth by the estimated density. Measurements are reported in snow data publications the same as snow course measurements, except that a subscript "a" follows the water-equivalent figures.

Snow Pressure Pillows

Pressure pillows are designed to measure snow water equivalent by indirectly weighing the snow that falls on them. The pillows are made from a number of materials, including butyl rubber, rubber fabric, neoprene, stainless steel, and galvanized sheet metal. A pillow is a flat fluid container, round or polygonal in shape. When filled with an antifreeze solution, the metal pillows are 1/2 to 1-1/2 inches thick and the other kinds are 2 to 4 inches thick.

Surface area of the pillows ranges from about 20 to 120 square feet, depending principally on site conditions and depth of snow to be weighed. A valve or other opening near an edge on the bottom makes it possible to fill the pillow with antifreeze and to connect it to a

pressure line. Another valve or other device in the top of the pillow vents air during filling.

Pressure transducers, electronic converters, and mechanical float devices are used to translate snow load into snow water equivalent for onsite recording and radio transmission.

Location

The location of pillows or similar automatic sensing device is determined in the same way as that of a snow course. Because of the expense of the installation, extreme care must be taken in selecting a station location. Locations chosen must provide optimum conditions for the type of water supply forecasting service needed.

If a pillow is to be installed on or near a snow course, it is generally desirable to place it at or near the sampling point on the snow course that most nearly represents the average snow water equivalent of the course.

The elevation and exposure of the site should be representative of as large a segment of snow conditions in the watershed as practical. In general, the sites are at medium or high elevations. At the present time, the density of automatic stations of one station for 200 to 400 square miles of snowpack watershed is considered best.

Since it is likely that data for most stations will eventually be transmitted by radio, there should be a radio path (generally line-of-sight) from the pillow site to a radio relay or base station (see ch. 3).

For pillow installation, the site should be well protected from wind and free from overhead interception of snow. Ideal locations are small (1/4 to 1/2 acre) mountain parks surrounded by high conifers or sheltered corners of larger parks. As for snow courses, avalanche paths should be avoided.

For ease of installation and maintenance, the site should be reasonably free of brush and trees and be accessible by truck, 4-wheel-drive vehicle, or all-terrain vehicle. But, for security, the site should be away from roads and frequently visited areas. If fencing is provided, it should be designed for easy manual or automatic dismantling before the snow season and for reassembly for the summer. Accessibility and security are secondary compared with topography, cover, and telemetry.

If rubber pillows are used, the site should be level. Metal pillows can be used on level or sloping sites. On sloping sites the earth surface should be smoothed to the natural slope of the land. Although the maximum permissible degree of land slope has not been determined, limited experience indicates that metal pillows work as well on a 20-percent slope as on level land. It is believed they would work well on slopes of as much as and perhaps exceeding 35 percent. On steeper slopes,

however, excessive snow creep and snow fracture lines may create problems in obtaining desirable readings.

Pillows should be located where the land slope is uniform. They should be well away from abrupt slope changes and from snow "fall-off" and "blow-out" zones around trees and other objects. Also they should not be near tree stumps, large rocks, rain gage stands, and other structures that can keep the snow from settling uniformly around the pillow as snow density changes during winter and spring. It is desirable that snow in the pillow area have uniform exposure to melting conditions.

The required distance from pillows to abrupt slope changes or objects varies with the depth of snowpack, amount of land slope, surface area of the pillow, and the uniformity of snow density in the vicinity. Until additional testing determines the most desirable distance, which varies with each of these factors, the distance should be at least 15 to 20 feet. If snow is likely to be more than 10 feet deep, increase the distance to 1.5 to 2 times the maximum snow depth expected.

Size

The size of pillow required depends on the uniformity of the snow pressure surface overlying the pillow. If pillows are correctly located with respect to site conditions and properly installed--so that no undue stress is created within the snowpack that could cause pressure waves across the pillow--the size can be reduced. Under such conditions pillows as small as 16 to 20 square feet have been found to report reliably snow water equivalents in excess of 80 inches.

Because there is a greater probability of uneven pressure areas developing within the deeper snowpacks, pillow surface area should be increased for the deeper snows. For this reason and because perfect site conditions cannot always be obtained, the following minimum pillow sizes are recommended: 40 square feet of pillow surface area for as much as 30 inches of snow water equivalent; 60 square feet for as much as 50 inches; 80 square feet for as much as 75 inches; and 120 square feet for 75 or more inches.

The additional surface area, and thus fluid volume, is more important, particularly for metal pillows that transfer liquid into stilling wells to drive mechanical float devices. Having extra fluid volume is less critical for pillows that are attached to pressure transducers where there is almost no liquid transfer.

Installation

Pillows should be tested for leaks or damage before they are taken to the field for installation. Fill pillows with liquid and apply an external pressure load to discover any leaks.

Rubber pillows should be installed on a level site. Clear the ground surface of vegetation and debris from an area the size of the pillow

and at least 5 feet more around the pillow. Remove larger brush, stumps, and rocks for at least 15 to 20 feet around the pillow.

Remove soil from the pillow foundation area to a depth of 3 or 4 inches or to a depth such that the completed installation leaves the top of the pillow about 1 inch above the surrounding soil surface. Roughly level and pack the soil so that there is no more than 1 inch of variation over the entire area. Cover the ground surface under the pillow with sand, sandy loam soil, or sawdust to a 1/2- to 1-inch depth and level it to within one-half inch. Dig a small trench near the edge of the pillow for an outlet and hose or pipe connection. Then fit the empty pillow onto the prepared foundation.

In some areas it has been found advisable to use 1/4-inch wire screen (4 in. by 4 in. galvanized hardware cloth) on the bottom and top of the pillow. The screen is fastened around the edges to keep out rodents and reduce damage by animals (see fig. 2-13).

To install a metal pillow, smooth the ground to the natural slope of the land. Install the pillow on the slope so that the pillow top has the same slope as the land. Prepare the ground surface and site as described for rubber pillows. The finished installation should leave the top edges of the pillow about one-half inch above the ground surface.

Attach outlet tubing to the pillow. If the ground is sloping, prop the pillow up to level it (perhaps using a 1-in. by 8-in. by 6-ft. board) while filling with antifreeze solution so that all air can be removed from corners. Fill the pillow, insert top filler plug, and lower to ground surface. Pack soil firmly under the edges of the pillow so that the bottom of the pillow is fully supported at all points.

If metal pillows are installed in multiple units of the 4- by 5-foot standard unit, they can be placed close together in a configuration such as 5 by 8 feet or 8 by 10 feet. They can also be separated more widely to provide a larger areal coverage and then plumbed as a single unit. This latter practice is probably desirable for site conditions where it is difficult to obtain a uniform snow-pressure surface.

Both rubber and metal pillows, if installed as described, overread during snowmelt or heavy rain when free water percolates to the bottom of the snowpack. This condition is the result of a buildup of a hydraulic head of water over the pillows before the water can move through the snow and off the pillow. Since water movement is slowest through the denser snows, overreading is greatest in deep, dense snowpacks and least in shallow, low density snow. In deep, dense snowpacks where density of the lower snow layers may exceed 50 to 65 percent, overreading may be as much as 5 to 10 inches when compared to the federal sampler.

WN-90347

Figure 2-13.--Installation of snow pressure pillow.

To obtain actual readings of snow water content during rain or melt periods, calibration measurements may be made using snow sampling tubes and pillow readings. The difference can be used as a corrective factor in adjusting reported pillow readings to eliminate the effect of water standing in the snow over the pillows.

Having both rubber and metal pillows slightly above the ground surface is important if the pillows transfer liquid into stilling wells. When buried below ground level, even if soil (sand, gravel, and the like) is smoothed across the top of the pillow so that it is level with the surrounding area, the pillows begin to underread. This situation arises because the snow bridges across the pillow area as liquid is transferred

to the stilling well. The underreading becomes more pronounced as snow depth increases. Using pressure transducers, which have almost no liquid transfer, corrects this problem. Also, the larger the pillow and the smaller the stilling well, the more the problem is minimized.

If it is desirable to bury a pillow and also have it record on a stilling well, the covering material should be mounded above the actual pillow area so that it is about an inch higher at the pillow center than the surrounding ground surface and then slopes downward to the pillow edge.

The following method of installing metal pillows should eliminate the problem of overreading during rain or snowmelt periods. Remove soil from the pillow foundation area, including a border around the pillow of 6 to 12 inches, to a depth of 2 to 4 inches or to a depth such that the completed installation leaves the top of the material covering the pillow at least flush with the surrounding soil or about an inch higher at the pillow center (particularly if using stilling wells or manometers).

After installing the pillow, then cover it and the adjacent pit area with clean crushed rock, fine gravel, or any lightweight material that will support the snow load and allow rapid water drainage away from the pillow during rain or snowmelt periods. The covering material should be about 1 to 2 inches deep depending on its efficiency in removing water. Soil is not recommended as a covering material because of its relative slowness in transmitting water.

The area bordering the pillow should be dug to a greater depth than the foundation area. Along with a channel leading from the pillow area for carrying melt water, it should also be filled with crushed rock, gravel, or other lightweight material.

Filling

The pillows have a pipe fitting that permits connection to a hose that can be led to a container for fluid, such as a barrel or can. If fluid is transported in barrels, the barrel should be at least 2 feet higher than the pillow to facilitate filling. The air vent on top of the pillow is opened, and the pillow is filled with the proper amount of fluid. For metal pillows, it is better to screw a 6- to 12-inch pipe nipple into the air vent to allow air to escape without excess fluid loss. The air vent is closed, and the outlet pipe capped until further connections are made.

It is desirable to fill metal pillows through the air vent, particularly if tubing of small diameter (e.g., 3/8 in.) is used for the pressure line to pressure transducer or stilling well. A pipe tee with two nipples is screwed into the air vent to allow air to escape while filling.

Rubber pillows should be filled with enough fluid, or about 1 to 2-1/2 gallons per square foot of surface area, so that they are about 2 or more inches thick.

Pillows of less flexible material such as sheet metal should be filled until all air is removed and fluid flows out the vent. The amount of fluid depends on the volume of the pillow as constructed. Usually 0.1 to 0.5 gallon of fluid per square foot of surface area is required.

The fluid used may be 100 percent methyl alcohol (methanol), a water-methanol mixture of at least 40 percent methanol, or a water-methanol-ethylene-glycol mixture that has a specific gravity of essentially unity for the normal winter temperatures to be encountered in a given area. A well mixed water-methanol-glycol solution (2 parts glycol, 3 parts methanol, 5 parts water) generally is preferred for economy, ease of transportation, and the lowest rate of change of specific gravity with temperature. This solution has a specific gravity of 0.990 at 60.3° F., 1.000 at 28.8° F., and 1.010 at -3.8° F. It meets the needs of most areas.

When standpipes or manometers are used for onsite reading or recording in areas of shallow snow with very cold winter temperatures, a solution of 2 parts glycol, 3 parts methanol, and 2-1/7 parts water may be preferred. This solution has a specific gravity of 0.980 at 55.2° F., 0.990 at 25.7° F., 1.000 at -2.2° F., and 1.010 at -32.9° F.

Caution: Methanol can be toxic to human beings if certain precautions are not taken when using it. See page 2-40 for information about how to use it safely.

Material

Pillows made of material such as butyl rubber or nylon-reinforced rubber (fuel tank materials) are satisfactory as are sheet metal and stainless steel.

Connections

The line from the pillow outlet tube to the standpipe or pressure transducer should be on a continuous downhill grade to avoid air lock. The connection to the standpipe or transducer should be below the pillow outlet to provide a positive head for the zero-load pillow reading. Fittings to the pillow and sensing devices vary. All connections must be made carefully with high-quality materials since there must be no leaks. The fluid-transfer line may be galvanized pipe, rubber hose (Ortac or similar quality), copper or plastic tubing. Tubing or pipe is preferred since rodents may damage rubber hose. Copper tubing corrodes in some soils.

Sensing Device Readout Installations

Buildings are recommended for housing readout equipment if pillow data are to be telemetered or recorded onsite. The most commonly used shelters are built of 1/2-inch plywood. Recommended dimensions are

either 4 or 8 feet deep by 8 feet wide by 12, 16, or 20 feet high, depending on amount of equipment, depth of snow, and type of antenna. Buildings 8 feet square are recommended where directional antennas are required. Dimensions should be large enough to allow working room for repairs to equipment. At times it may be necessary to use such buildings for overnight shelter.

Shelters should be installed so that the floor is lower than the fluid level in the pressure pillow. Entrance to the shelters from above the winter snowpack can be provided by upper access doors and ladders. The recommended minimum distance between the shelter and pillow is 15 to 20 feet.

An enclosed, insulated area may be provided as near the shelter floor as possible or in a waterproof container located under the floor and available through a trap door, so that a stable temperature is kept for transducers, batteries, and radio equipment. The upper 4 feet of the shelter may consist of 2-inch by 4-inch studding covered by fiberglass siding. This area is used for radio antennas. Louvers, designed to keep out blowing snow, may be installed near the roof for air ventilation.

A pillow may be installed near a snow course with the intention of taking periodic comparative readings to establish a correlation between the two before installing onsite recording or telemetry equipment and a shelter house. In such a case, the following installation is recommended for readout of the pillow.

The fluid-pressure line leading from the pillow can be attached to a post of galvanized pipe 2 or 2-1/2 inches in diameter set in concrete. The bottom of the pipe is sealed liquid tight with a pipe cap. A pipe cap is also used at the top of the pipe. A hole is drilled in the pipe post about 18 inches above the bottom, and a pipe coupling is welded to the pipe over the hole. A short length of pipe such as a nipple can be attached to the coupling to remove the connecting point with the fluid-pressure line far enough away from the pipe to allow room for a concrete block. A pipe tee attached to the end of the nipple provides for a future connection to a pressure transducer.

As an alternate method, instead of welding a coupling to the pipe post, the hole may be tapped and an adapter used; e.g., tap with a 1/4-inch pipe thread and use a 1/4-inch National Pipe Thread (NPT) by 3/8-inch brass adapter. Drill the hole far enough above the bottom of the pipe so that the pipe can be set deep enough in the ground to have a firm base without burying the pressure line excessively deep.

If possible, the pipe post should be located so that the liquid level in the pipe is below the ground surface at the zero reading. This location aids in maintaining as near a stable temperature as possible. Manometer levels then are always below the ground or snow surface.

Measurement from the top of the pipe to the liquid level can be taken by using a popper, such as the U.S. Geological Survey sometimes uses, on the end of a steel tape marked in hundredths of a foot. A popper can be constructed of tubing 1-1/2 to 2 inches in diameter by 4 to 6 inches long. The top is sealed and weighted if desired at or near the top end by soldering a round piece of metal of appropriate size to the tubing. A snap hook is attached to the top for connecting to the steel tape. The popper is dropped rapidly down the pipe until it hits the liquid at which time it pops. Successive tries allow readout to the nearest hundredth of a foot.

Calibration

Analysis of pillow readings indicates that snow water equivalent in inches is approximately equal to the increase in fluid level in inches in a standpipe, corrected for fluid density. Accuracy is considered to be equal to or better than that achieved by sampling with a standard snow tube under typical field conditions, even after correcting for sampling errors for individual cutters.

If commonly available pressure transducers are used, telemetry readout values at the base station give inches of water equivalent directly. If sensing devices are used that telemeter liquid levels, then reported values must be multiplied by the density of the standpipe fluid.

The zero-water equivalent value for semirigid pillows that have an initial static head above all points of the pillow, such as happens when pillows transfer liquid into stilling wells, is best determined when fluid temperature is about 32° F. in the pillow, in the pressure line from pillow to transducer or standpipe, and in the standpipe. Reference to a density-temperature chart for the antifreeze solutions in use shows that temperature variations during the year are great enough in many cases to introduce significant errors from changes in fluid density. The range of temperature variations during the season is as much as 100° F. in some areas (e.g., from −20° F. to +80° F.).

Even changes in soil temperature can be significant in shifting the zero point if the tubing leading from the pillow to a pressure transducer is long. The density of alcohol and acceptable alcohol-water mixes changes by about 0.011 when the temperature drops from about 55° F. (a common mountain summer soil temperature at the 4-inch depth) to 32° F. If the pillow is 50 feet (600 inches) from the pressure transducer or small-diameter manometer, this change alone can cause a significant shift in zero-point readings (600 inches x 0.011 = 6.6 inches). This shift becomes less noticeable if the pressure line is connected to a standpipe instead of a transducer because of the difference in ratio of the cross-sectional area of the pressure line and standpipe. For example, if the pressure line is 3/8-inch copper tubing, the ratio of areas with standpipes of 2, 2-1/2, and 4 inches in diameter is 28.4, 44.4, and 113.8 to 1, respectively. For a 4-inch diameter standpipe the height change would be 6.6 ÷ 113.8 = 0.058 inches.

When using flexible pillows of rubber materials, as long as the height of liquid in a stilling well is not appreciable, the zero-water equivalent value required for ordinary accuracy can be determined at any time. The pillow itself acts as a large stilling well of very short height, allowing for expansion of fluid from the pressure line. If a metal pillow attached to a transducer is in a level location and the liquid level at zero point is not above the pillow, the metal will essentially "float" on the liquid similar to a rubber pillow and allow for liquid expansion with little or no pressure change.

If corrections for fluid density caused by temperature fluctuations are applied to readout values, the total height of the fluid in the standpipe should be considered, not just that above the zero-point reading. Effects of solar heating of pillow fluid are more pronounced with metal than with rubber pillows, because the metal pillows have a smaller volume of liquid to be heated. Insulation materials over the metal pillows, such as fine gravel or crushed rock, reduce liquid expansion due to solar heating.

<u>Fluid Displacement</u>
The pillow system should be designed so that no more than 10 percent of the fluid content of the pillow is displaced, under full load, into the connecting lines and standpipes.

<u>Fluid Density</u>
For standpipe readouts, the density of the fluid in the pillow must be measured. This is done by taking a sample (about a pint) and weighing a known volume such as 100 cubic centimeters. Density can also be measured by using an hydrometer. Other methods are given in chemical handbooks or by manufacturers of a specific product.

Fluid density should be determined for each pillow since separate lots of the same kind of product often vary due to different additives included by manufacturers.

<u>Relating Data to Existing Snow Courses</u>
Many automatic snow-sensing stations are located on or near existing snow courses. In practice, it is necessary to have at least a 10-year record of snow water equivalent or any other variable to use the data for streamflow forecasting. This period depends to some degree on the length of record of other data used for forecasting. It is unlikely that the snow water equivalents measured on the pillow will be exactly the same as the snow course readings. Therefore, if continuity of data is desired for forecasting, a relationship must be established between water equivalents measured on the existing course and the pillow.

To calibrate the pillow to the snow course, concurrent measurements on the snow course and the readout of the pillow are needed. A minimum of nine readings over a 3-year period should be obtained. An example of one method by which this relationship can be determined follows.

	First year			Second year			Third year		
Approx. date	Snow course	Pillow	Ratio	Snow course	Pillow	Ratio	Snow course	Pillow	Ratio
Mar. 1	20.3	24.1	0.81	15.1	19.6	0.77	30.5	38.0	0.80
Apr. 1	27.2	34.3	.79	25.0	30.9	.81	31.3	39.0	.80
May 1	19.6	23.2	.84	27.8	32.8	.84	26.8	32.9	.81

The mean ratio of the snow course to pillow readings is 0.797 or 0.800.

If a variation of more than 0.05± from the mean ratio is observed and if it is desired to have the pillow record duplicate the snow course, the pillow probably should be relocated. For such duplication, no more than 0.07± in numerical ratio from the mean ratio should be tolerated. Because of variations in accumulation and particularly in melt rates, it may be necessary to extend the number of years of calibration to obtain a separate calibration ratio for individual months.

Graphic and mathematical regression correlation techniques can also be used to determine the relation between snow course and pillow.

Correlation and ratio information is recorded on and made a part of the history of the snow course and automatic station biographies (fig. 2-3). Measured or estimated data from a snow pillow and from a standard snow course are reported separately as two stations, even though both are at the same site. Data to be published are discussed under Snow Data Tables in chapter 7.

Repair

Small isolated leaks in the flat surface of rubber pressure pillows can be repaired by using the standard methods of patching tire innertubes. It is not practical to try to repair leaks along seams or large rips in the field. The pillow must be returned to the factory or replaced. For similar leaks on neoprene pillows, neoprene patches can be applied with special glue. Metal pillows generally need to be drained before enough heat can be maintained in the metal to allow soldering of leaks.

Readout Problems

The readout of snow water equivalent, particularly for poorly installed and poorly located pillows, tends to vary when the snowpack is becoming isothermal. This occurs in periods of substantial surface melt followed by partial freezing of free water in the snowpack during colder periods. The variation appears to be related to pressure changes caused by stress or structural characteristics in the snowpack induced by fluctuations in

temperature. After early spring when melting has relieved internal snowpack stress, readings stabilize and report snowpack changes in the normal manner. This period of varying readings may be as long as 2 weeks, or it may not occur at all, particularly if pillows are properly located and installed.

Precipitation

Gages

Numerous kinds of recording and nonrecording precipitation gages are used to collect precipitation. Those used in the data collection network at high elevations generally are of the storage type and are located at or near a snow course.

The dimensions and shapes of typical gages are shown in figures 2-14 through 2-18. The capacity of the gage selected for a given site depends on the depth of snow, not on the equivalent depth of water, that can be expected to accumulate in the interval between visits to the site. Unless some provision is made to melt and mix the snow catch with the recharge solution, snow falling in the precipitation gage settles on the recharge solution without appreciable mixing. If an ethylene glycol or calcium chloride antifreeze solution is used, any snowmelt results in a solution at the top of the recharge so diluted that ice soon forms. Snow then builds up on the ice until the gage is full. The gage then caps over, or snow is blown away, or both occur.

Although no ice block forms if an adequate quantity of glycometh antifreeze is used, should the gage be allowed to become too full and the antifreeze too diluted for rapid snow melting during a heavy storm, snow also may fill the gage and a true catch is lost.

The gage, therefore, should be capable of handling any snow accumulation that occurs between visits. If visits are made monthly to obtain readings, a standard gage 8 inches in diameter and 42 inches high is adequate in most areas. However, longer gages or gages of larger diameter, or both, may be needed in heavy snowfall areas.

At some sites, because of their inaccessibility, it may be feasible to take readings only once per season or per year. In the colder, dry snow areas, a gage such as that shown in figure 2-17 is recommended. In relatively warmer areas and areas having heavy wet snow, it is advisable to use a gage such as shown in figure 2-16. In areas where snow is likely to bridge the gage orifice, gages having a top 12 inches in diameter are preferred. Bridging occurs less frequently with these gages compared to gages that have a top 8 inches in diameter.

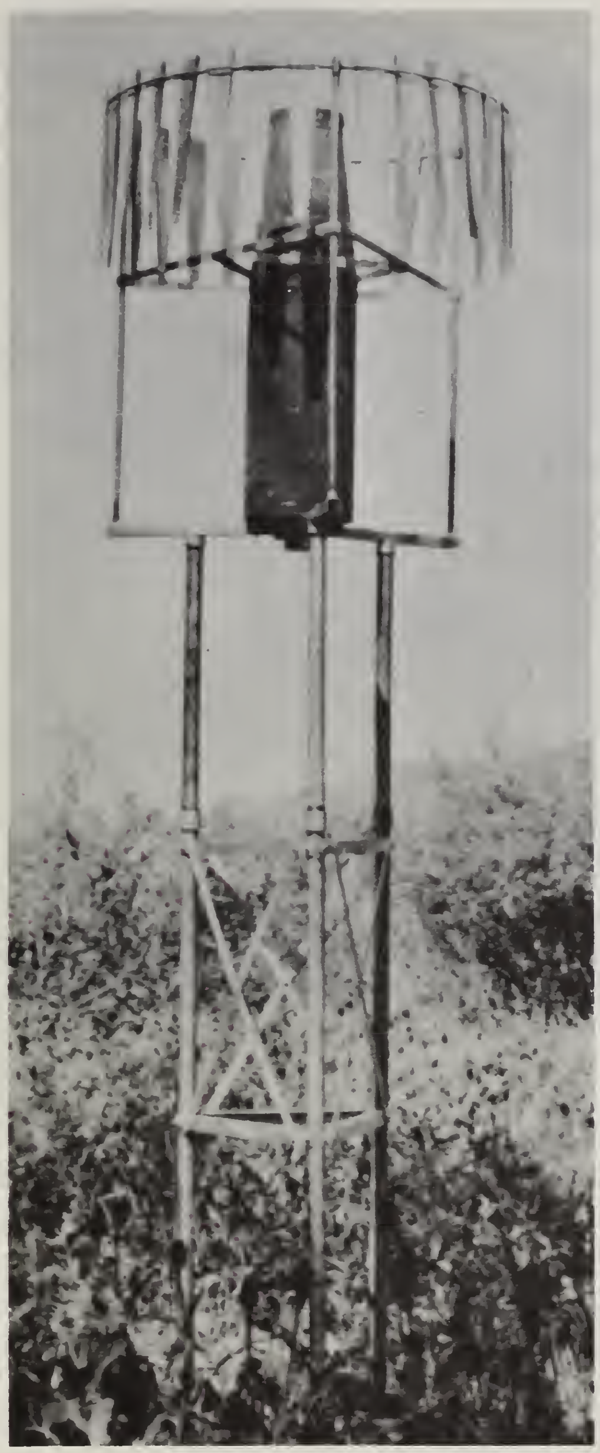
The slopes of the conversion sections of gages should be no flatter than 6 vertical to 1 horizontal. Heat absorption for melting the snow can be increased by painting the outside of the gage with a flat black paint.

BN-38794

Figure 2-14.--Precipitation gage tower of pipe construction, with single pipe base stand. Usable with either constant or variable diameter precipitation gages.

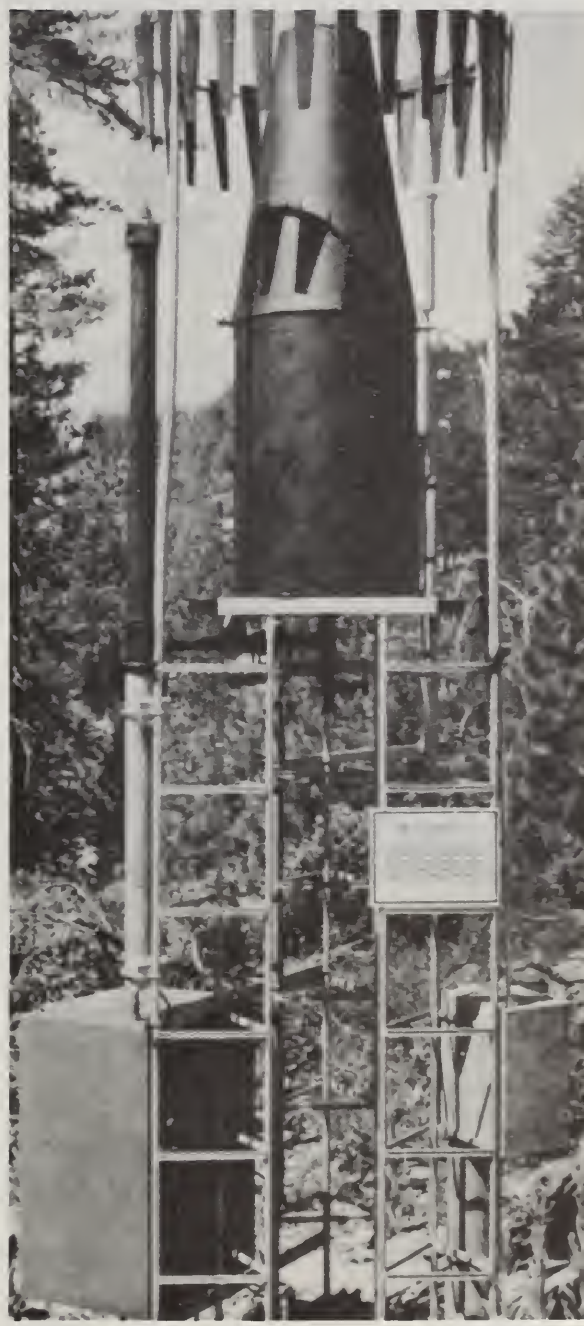
The life of the gage can be prolonged by painting the inside with an acid-alkali resistant paint.

If precipitation data are to be telemetered, the gages of larger, variable diameter provide free liquid at the edge of snow or ice blocks more readily, thus giving more reliable pressure for a pressure transducer. But this condition is offset by the correction required to compensate for the ratio of the area of the gage opening to the area of the



BN-38662

Figure 2-15.--Precipitation gage tower of pipe construction, with three vertical pipe base for use in deep snow country. Gage orifice 14 feet from ground. Higher gage obtained with longer pipe lengths.

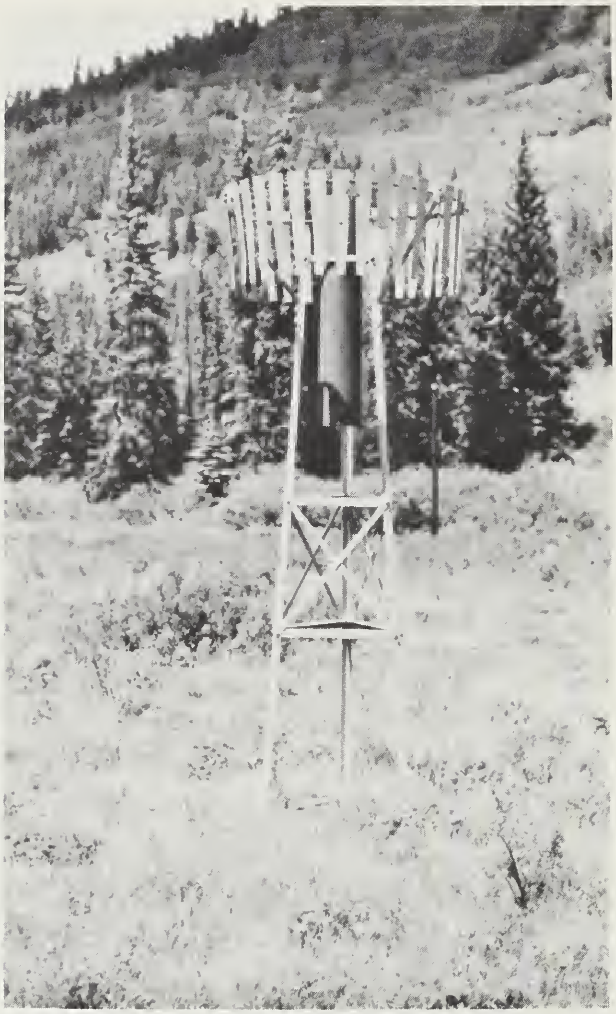


Corps of Engineers

Figure 2-16.--Combination of three welded conduit towers to provide base for holding windshield and precipitation can. Castle type.

Rex Industries

Figure 2-17.--Welded steel tubing support tower suitable for 8-inch constant diameter precipitation can.



BN 38795

Figure 2-18.--Precipitation gage tower of angle iron frame. Usable with either constant or variable diameter precipitation gages.

storage section, which decreases the accuracy of telemetered readout values.

Limited experience with telemetry of data from straight-sided gages of constant diameter indicates that results are acceptable if enough gly-cometh antifreeze is used.

Towers

The tower must be high enough so that the orifice of the gage is at all times above the level of the maximum snowfall expected at the site. The maximum snow depth recorded at nearly 90 percent of all western snow

courses is less than 10 feet. About 80 percent of the courses have never had more than 8 feet, and about 60 percent have never had more than 6 feet of snow. The average snow depth at most courses varies between 50 and 70 percent of the maximum recorded snow depth. Snow survey records should provide some information on snow depth and thus the tower height needed for a particular area.

If towers for the purpose needed are not available from commercial sources, they can be made at local shops. Current updated drawings and specifications for towers commonly used by SCS can be obtained from the Water Supply Forecasting Unit, WRTSC, Soil Conservation Service, 701 N.W. Glisan Street, Portland, Oreg. 97209.

Site Selection

The best site is one located in a small open area in a coniferous forest where wind movement is minimal. The tops of trees should be at least 30° above the horizontal plane of the gage top to provide good shielding. Tops of fully grown trees, if trees are of uniform height, should not be more than 60° above the horizontal. Open windswept areas, open mountain tops, and areas too near the lee side of windy ridges should be avoided.

In choosing a site in the mountains, it is better to sacrifice some elevation to get a site on which vegetation offers natural shielding. If natural shielding can be found on only one side, the gage should be located where maximum protection is provided against the prevailing storm winds. Sites should be in major water-producing areas. Avoid small areas where precipitation may be influenced by local topographic conditions. Box canyons and sheer cliffs on windward slopes tend to catch moist air and force it upward, causing excessive precipitation locally. Abrupt, high ridges also cause excessive precipitation for relatively short distances on their downwind side. Sites in such areas should be avoided unless they constitute the major water-producing area of the watershed being instrumented.

If possible, choose sites where the gages receive a minimum amount of attention from the public, thus preventing loss of record because of disturbance by visitors or by vandals.

Installation

Regardless of the kind of rain-gage tower being installed, it is desirable to use enough concrete around the leg(s) of the tower for a firm base. Towers with three or four legs usually are placed in holes dug to a depth of about 2-1/2 feet. About 150 pounds of dry gravel-concrete mix make enough concrete to hold each leg firmly in place (five 90-pound sacks of mix for a three-legged tower). Towers with a one-leg support are placed in a hole 2-1/2 to 4 feet deep, depending on the height of the gage. Ordinarily about three 90-pound sacks of dry gravel-concrete mix make enough concrete to hold the pipe firmly.

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A spirit level or plumb bob should be used to insure the vertical positioning of the tower. A straight edge and spirit level should be used to level the gage and baffle assembly. The top of the gage should be adjusted so that the top of the baffles are 1/2 inch to 1 inch above the top of the gage.

Mapping and Installation Data

If the precipitation gage is installed on or near an existing snow course, the location is shown on the snow course sketch map. If it is separate from a snow course, a map similar to a snow course map is prepared that shows terrain features, elevation, area location in latitude and longitude (also section, township, and range), and station number. The standard numbering system is followed.

The type of tower, dimensions and capacity of the precipitation can, and the height of the gage orifice above the ground is recorded.

Use of Antifreeze Solutions

At present two types of antifreeze solution, ethylene glycol and calcium chloride, are in common use in storage gages. A third, glycometh, is expected to come into common use.

Glycometh

This solution is 40 percent ethylene glycol and 60 percent methanol (methyl alcohol). Its specific gravity is between that of ice and water so that, when snow or ice melts, the water sinks to the bottom of the solution, mixing enroute. If water reaches the bottom of the solution, it refreezes and rises to the top. Thus, the solution is self-mixing. The alcohol rapidly melts snow or ice.

Caution: Methanol is toxic to human beings if ingested, inhaled, or absorbed through the skin, and it is harmful on repeated skin contact. It is flammable and so presents both fire and health hazards. Mixtures are not dangerous in open air. Avoid skin contact and wear goggles to prevent accidental contact with the eyes. About one-half of all serious cases of methanol poisoning result in some impairment of vision, which is usually permanent. With ordinary precautions there should be no problems. Read safety materials on methanol that can be supplied by your snow survey supervisor.

Ethylene glycol (Prestone)

This solution can be used if there is no objection to having an ice plug during part of the winter season or if some type of mixing action is provided. It is easier to use than calcium chloride and has better antifreeze characteristics through a wider range of solution concentrations. An initial charge of 80 percent solution (1 gallon glycol to 1 quart water) but no higher than 89 percent (1 gallon glycol to 1 pint water) is recommended. Pure glycol freezes at 0° F.

Table 2-1 gives the freezing points of solutions after different amounts of precipitation (inches) have been added to the initial antifreeze

Table 2-1.--Freezing temperatures of ethylene glycol--precipitation solutions

Precipitation added (8-in. orifice)	Initial charge (quarts)--Prestone/water												
	1/0.25	2/0.50	3/0.75	4/1	8/2	12/3	16/4	20/5	24/6	28/7	32/8	36/9	40/10
Inches	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
1	-27	-60	-77										
2	- 1	-27	-47	-60									
5	18	5.5	- 6	-17	-50	-68	-80						
10	26	18	12	5.5	-17	-35	-50	-60	-68	-74	-80		
15		23	18	14	- 2	-17	-30	-41	-50	-57	-62	-68	-72
20		26	22	18	5.5	- 6	-17	-27	-36	-43	-50	-54	-60
25			24	21	11	0	- 9	-17	-25	-32	-39	-45	-50
30				23	14	5.5	- 2	-10	-17	-24	-30	-36	-41
40					18	12	5.5	- 1	- 6	-12	-17	-22	-27
50					21	16	11	5.5	1	- 4	- 9	-13	-17
60					23	18	14	10	5.5	1.5	- 2	- 6	-10
70						20	16	13	10	5.5	2	- 2	- 5
80						22	18	15	12	9	5.5	3	- 1
90						23	20	17	14	11	8	5.5	3
100						24	21	18	16	13	11	8	5.5
110							22	19	17	15	12	10	8
120							23	20	18	16	14	12	10
130							24	21	19	17	15	14	12
140								22	20	18	16	15	13
150								23	21	19	17	16	14

solution of 80 percent ethylene glycol and 20 percent water. The table gives data for gage openings 8 inches in diameter. Depth of the can or diameter of the storage section, or both depend on the frequency of observations and on the amount of precipitation to be measured.

Unless the precipitation and recharge solution are mixed artificially, any mixing is due principally to radiant heat received on the sides and bottom of the gage. Because of its heavier specific gravity, most of the ethylene glycol remains in the bottom of the can and does not freeze. The initial charge should be enough for a 5-inch depth in the gage, regardless of gage diameter. If there is any question as to the amount of charge to use, it is better to overcharge rather than undercharge the gage.

Calcium chloride

Although less expensive than ethylene glycol, calcium chloride has poorer antifreeze characteristics if there are large changes in concentration. If a rain gage 8 inches in constant diameter is used and is recharged monthly, calcium chloride can be used. Use 2 pounds chloride and 6 ounces oil, add 1 quart water, and mix until the chloride is completely dissolved. If the gage is to be left for 2 months or more, use two or three charges of chloride. More charges seldom accomplish much since in the gages of constant diameter there is little mixing of precipitation and solution. Some ice may form in the gage.

If calcium chloride is used in gages of larger and variable diameter, be sure that the chloride is thoroughly dissolved so that solid chloride does not block drain valves. When mixing large quantities of commercial calcium chloride, mix by weight in the proportion of 40 percent chloride and 60 percent water. Do not use a greater concentration of calcium chloride.

Recommended amounts of recharge solution to use for various amounts of precipitation and freeze temperatures to be expected are shown on the back of the precipitation data form, SCS-ENG-2 (figs. 2-19, 2-20, and 2-21).

Use of Oil Film

An oil film is used to cover the charge in a gage to prevent loss of water by evaporation. Amounts and recommended types of oil also are shown on the back of the precipitation data form. Do not use transformer or silicone oils as these are not effective evaporation retardants. SAE 10, nondetergent and multiviscosity motor oils having an oil film 0.3 inches or more thick, are satisfactory.

Measuring Techniques

The amount of precipitation can be determined by measuring either its weight or volume. The weight method generally is more accurate. Measurement errors in the volume method are due to expansion and contraction of both liquid and container as temperatures change.

Any accurate hand scale having a capacity of 40 or more pounds and its smallest divisions no larger than 1/4-pound increments is satisfactory. But the 40-pound (two revolutions) scale shown in figure 2-22 is preferred since it gives a direct reading of inches of precipitation caught in a gage with an orifice of 8 inches in diameter. If used with a gage having an orifice of 12 inches in diameter, the readings should be divided by 2.25 to determine true precipitation.

Rain-gage scales should always be checked before a reading to be sure they are set on zero. They can be adjusted to the zero reading by turning the little screw on the bottom of the balance arm at the bottom of

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File Code ENG-21

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Federal and State Cooperative Snow Surveys

PRECIPITATION DATA

Precipitation Station Elk Ridge

State Utah Drainage Basin Weber River

Observer J. Young - M. Marchant

Month	Day	Year	Precipitation	Readings
3	30	70	Current	15.25
2	27	69	Previous	8.73
Please check-			Catch, inches	6.52
Readings include:			After recharge	7.65

Gage plus solution weight ✓ Scale adjusted to zero ✓ Yes ___ No

Solution weight only ___ If no, scale reading was ___

CURRENT WEIGH-OUT READINGS

Auxiliary Bucket No.	Solution plus Aux. Bucket (1)	Empty Auxiliary Bucket (2)	Net Solution Weight (1)-(2)	Remarks
				on weigh out, read bucket weight before filling with solution.
1				
2				
3				
4				
5				
6				
7				
8				
Total solution weight				
Weight, removable gage				
Total weight				

RECHARGE READINGS

1				on recharge, read bucket
2				weight after emptying
3				into gage.
4				
Total solution weight				

No. 1 of 1 Sheets Compiled by: J. Y. Checked by: M.M.

Note.-Please fill in while in the field. Check items as appropriate.

Time 9:30 am

Weather and Snow Conditions

✓ Clear, ___ Partly cloudy, ___ Overcast, ___ Raining,

___ Snowing, ___ Blowing, ✓ Freezing, ___ Thawing,

Snow line elevation 5,500 ft. Inches of new snow 15 in.

Snow depth on ground 84 in. Water content 34 in.

Type anti-freeze used		Recommended initial charge ratio:
Glycometh	___	40% glycol, 60% methanol
Ethylene glycol-- (Prestone)	___	1 gallon glycol to 1 pt. or 1 qt. water
Calcium chloride	✓	3.75" salt + 6.25" water-weight on precip scales.
Other	___	

Antifreeze charging quantities

Gages with 8" orifices:

Glycol-

Final freeze temp. approx. 5°F.-1 gallon glycol (plus 1 qt. water) per ea. 10" precip.

Final freeze temp. approx. 23°F.- 1 gallon glycol (plus 1 qt. water) per ea. 30" precip.

Glycometh-

Final freeze temp. approx. -4°F.- 1 gallon solution for ea. 10" precip.

Final freeze temp. approx. 24°F.- 1 gallon solution for ea. 30" precip.

Gages with 12" orifices - 2.25 gallons of glycol or glycometh for each condition.

Oil Film - Amount of oil to produce film approx. 0.15 to 0.20 inches thick to prevent evaporation in precipitation gages having storage section diameters as shown: With Glycometh add one-third to quantities shown.

Diameter, Inches	8	12	16	20	24	30
Oil in liquid ounces	6	12	24	36	54	84

Type Oil

Oils having SUC ratings near 70-100, pour point of -60°F or lower.
Examples-Refrigerant oils such as Texaco's Capello AA; Standard's Rycon #11.

Check Measurement - Tape or stick distance from gage orifice to liquid surface

Before weigh-out 31.75 inches; After Recharge 39.35 inches.

Test Load - Current Weight ___ inches; Base Weight ___ inches.

Remarks:

Figure 2-19.--Notes for precipitation gage read and recharged monthly.

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3-71
File Code ENG-21

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Federal and State Cooperative Snow Surveys

PRECIPITATION DATA

Precipitation Station Fish Springs

State Utah Drainage Basin Duchesne River

Observer L. Wilson – L. Hunt

Month	Day	Year	Precipitation	Readings
3	31	70	Current	38.05
11	1	69	Previous	10.50
Please check-			Catch, inches	27.55
Readings include:			After recharge	8.40

Gage plus solution weight ✓ Scale adjusted to zero ✓ Yes ___ No

Solution weight only ___ If no, scale reading was ___

CURRENT WEIGH-OUT READINGS

Auxiliary Bucket No.	Solution plus Aux. Bucket (1)	Empty Auxiliary Bucket (2)	Net Solution Weight (1)-(2)	Remarks
1	14.50	2.00	12.50	on weigh out, read bucket
2	14.00	2.00	11.80	weight before filling with
3				solution.
4				
5				
6				
7				
8				
Total solution weight				
Weight, removable gage			13.75	with remaining solution
Total weight			38.05	

RECHARGE READINGS

1	can with solution			on recharge, read bucket
2	weighed for recharge			weight after emptying
3	as shown above			into gage.
4				
Total solution weight				

No. 1 of 1 Sheets Compiled by: L.W. Checked by: L.H.

Note.-Please fill in while in the field. Check items as appropriate.

Time 9:15 am

Weather and Snow Conditions

___ Clear, ✓ Partly cloudy, ___ Overcast, ___ Raining,

___ Snowing, ✓ Blowing, ✓ Freezing, ___ Thawing,

Snow line elevation 5,700 ft. Inches of new snow 12 in.

Snow depth on ground 65 in. Water content 25 in.

Type anti-freeze used		Recommended initial charge ratio:
Glycometh		40% glycol, 60% methanol
Ethylene glycol-- (Prestone)	✓	1 gallon glycol to 1 pt. or 1 qt. water
Calcium chloride		3.75" salt + 6.25" water-weight on precip scales.
Other		

Antifreeze charging quantities

Gages with 8" orifices:

Glycol-

Final freeze temp. approx. 5°F.-1 gallon glycol (plus 1 qt. water) per ea. 10" precip.

Final freeze temp. approx. 23°F.- 1 gallon glycol (plus 1 qt. water) per ea. 30" precip.

Glycometh-

Final freeze temp. approx. -4°F.- 1 gallon solution for ea. 10" precip.

Final freeze temp. approx. 24°F.- 1 gallon solution for ea. 30" precip.

Gages with 12" orifices - 2.25 gallons of glycol or glycometh for each condition.

Oil Film - Amount of oil to produce film approx. 0.15 to 0.20 inches thick to prevent evaporation in precipitation gages having storage section diameters as shown: With Glycometh add one-third to quantities shown.

Diameter, Inches	8	12	16	20	24	30
Oil in liquid ounces	6	12	24	36	54	84

Type Oil

Oils having SUC ratings near 70-100, pour point of -60°F or lower.
Examples-Refrigerant oils such as Texaco's Capella AA; Standard's Rycon #11.

Check Measurement - Tape or stick distance from gage orifice to liquid surface

Before weigh-out 9.45 inches; After Recharge 39.10 inches.

Test Load - Current Weight ___ inches; Base Weight ___ inches.

Remarks:

Figure 2-20.--Notes for precipitation gage not visited for several months, with precipitation exceeding capacity of weighing scales. Auxiliary container used.

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3-71
File Code ENG-21

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Federal and State Cooperative Snow Surveys

PRECIPITATION DATA

Precipitation Station Lookout Pass

State Utah Drainage Basin San Pitch River

Observer L. Carlson - D. Beck

Month	Day	Year	Precipitation	Readings
3	30	70	Current	67.75
10	1	69	Previous	18.50
Please check-			Catch, Inches	49.25
Readings include:			After recharge	17.85

Gage plus solution weight ______ Scale adjusted to zero ✓ Yes ___ No

Solution weight only ✓ If no, scale reading was ______

CURRENT WEIGH-OUT READINGS

Auxiliary Bucket No.	Solution plus Aux. Bucket (1)	Empty Auxiliary Bucket (2)	Net Solution Weight (1)-(2)	Remarks
1	20.50	3.00	17.50	on weigh out, read bucket weight before filling with solution.
2	18.90	3.20	15.70	
3	19.40	3.25	16.15	
4	21.60	3.20	18.40	
5				
6				
7				
8				
Total solution weight			67.75	
Weight, removable gage				
Total weight				

RECHARGE READINGS

1	21.05	3.20	17.85	on recharge, read bucket weight after emptying into gage.
2				
3				
4				
Total solution weight			17.85	

No. 1 of 1 Sheets Compiled by: L.C. Checked by: D.B.

Note.-Please fill in while in the field. Check items as appropriate.

Time 11:15 am

Weather and Snow Conditions

✓ Clear, ___ Partly cloudy, ___ Overcast, ___ Raining,

___ Snowing, ___ Blowing, ✓ Freezing, ___ Thawing,

Snow line elevation 5,500 ft. Inches of new snow 17 in.

Snow depth on ground 120 in. Water content 48 in.

Type anti-freeze used		Recommended initial charge ratio:
Glycometh		40% glycol, 60% methanol
Ethylene glycol-- (Prestone)	✓	1 gallon glycol to 1 pt. or 1 qt. water
Calcium chloride		3.75" salt + 6.25" water-weight on precip scales.
Other		

Antifreeze charging quantities

Gages with 8" orifices:

Glycol-

Final freeze temp. approx. 5°F.-1 gallon glycol (plus 1 qt. water) per ea. 10" precip.

Final freeze temp. approx. 23°F.- 1 gallon glycol (plus 1 qt. water) per ea. 30" precip.

Glycometh-

Final freeze temp. approx. -4°F.- 1 gallon solution for ea. 10" precip.

Final freeze temp. approx. 24°F.- 1 gallon solution for ea. 30" precip.

Gages with 12" orifices - 2.25 gallons of glycol or glycometh for each condition.

Oil Film - Amount of oil to produce film approx. 0.15 to 0.20 inches thick to prevent evaporation in precipitation gages having storage section diameters as shown: With Glycometh add one-third to quantities shown.

Diameter, Inches	8	12	16	20	24	30
Oil in liquid ounces	6	12	24	36	54	84

Type Oil

Oils having SUC ratings near 70-100, pour point of -60°F or lower.
Examples-Refrigerant oils such as Texaco's Capella AA; Standard's Rycon #11.

Check Measurement - Tape or stick distance from gage orifice to liquid surface

Before weigh-out 20.3 inches; After Recharge 42.5 inches.

Test Load - Current Weight ______ inches; Base Weight ______ inches.

Remarks:

Figure 2-21.--Notes for precipitation gage permanently attached to tower. Solution weighed separately with auxiliary container.

BN-38663

Figure 2-22.--Weighing-type precipitation scales for use with gages having an 8-inch top diameter opening.

the scales. If for any reason the scales cannot be adjusted to zero, the actual plus or minus reading from zero should be recorded in the notes. When weighing the gage, be sure that the gage is hanging freely.

In reading the scales, be sure to count the revolutions. Scale readings of 0 to 11 inches of precipitation pertain to the first revolution of the pointer and 11 to 22 inches to the second revolution. Occasionally, notes are turned in that show the current reading to be less than the previous reading, thus indicating the possibility of error. Often the first revolution has not been counted. If 11 is added to the reported reading, a precipitation catch that appears reasonable is indicated. Checking with the observer generally shows that the gage actually had more precipitation in it than would have been true for one revolution.

Replace torn, scratched, or wornout decals on the face of the scales. New decals are available at SCS state offices. Once a dial pointer has been removed, it is likely to come off again unless it is soldered on. If the dial pointer comes off and is lost while in the field, whittle out a wood pointer or use a pencil with clips as a temporary pointer.

Since the maximum reading that can be obtained on this kind of scale is between 24 and 25 inches (starting the third revolution), any precipitation catch of more than 11 to 14 inches cannot be read since the weight of gage and charge adds to the total. The exact amount varies with the weight of the rain gage and the amount of initial recharge solution. The amount to be weighed often exceeds the capacity of the scale particularly if the gage has a catch of several months. If this is so, an auxiliary bucket or can, into which increments of the solution are poured or drained, is used and weighed. The total weight of the solution and rain gage is determined. The tare weight of the bucket before filling must be subtracted from each weighed increment. Subtracting the gage recharge weight from the total weight then gives net precipitation. When pouring or draining the solution into the auxiliary bucket, great care must be used to avoid spilling any of the solution.

Normally it is impractical to remove for weighing storage gages of large capacity that are permanently or semipermanently attached to the rain-gage stand. When such a gage is first put into operation, an antifreeze solution should be poured into the gage to wet the sides and bottom. This is drained out and the amount of recharge solution to be poured into the gage is weighed. Note that on recharge the tare weight of the bucket to be subtracted is the weight of the bucket after it has been emptied into the storage gage. These larger gages must be flushed out or otherwise cleaned periodically to remove leaves, insects, birds, sediment, and the like. At least once a year all gages should be examined for leaks.

Recording Data

Precipitation measurements should be recorded on the precipitation data form (figs. 2-19, 2-20, and 2-21) as follows:

Figure 2-19 illustrates a set of notes for a gage that is removed from the tower, read, and recharged monthly. The total weight (inches) on the scale is recorded under "Current" readings and "After recharge" readings.

Figure 2-20 shows a set of notes for a removable gage that was not visited for several months and that received enough precipitation so the weight of the gage exceeded the capacity of the precipitation scales. Note that the empty weight of the auxiliary container is determined each time before the solution is drained into it.

Figure 2-21 illustrates a set of notes for a large storage gage that is permanently attached to the rain-gage tower. This figure is similar to figure 2-20 except that total solution weight is determined on both current and recharge readings without including the weight of the gage. Note that the empty weight of the auxiliary bucket is determined <u>before</u> filling when obtaining the current solution weight and <u>after</u> emptying when obtaining the recharge weight. When this type of gage is first installed, the antifreeze solution should be poured into the gage to wet the sides and bottom of the gage and then drained out. The recharge reading is obtained as noted earlier.

Soil Moisture and Soil Temperature

Soil moisture is measured to increase the accuracy of forecasts made primarily from indexes of snow water equivalent. Deficiencies in soil moisture must be satisfied before snowmelt water is available for runoff. The rate of snowmelt is generally less than the infiltration rate of the soils beneath the snowpack. Exceptions to this are soils that have an unusually low infiltration rate, frozen soils, or saturated soils.

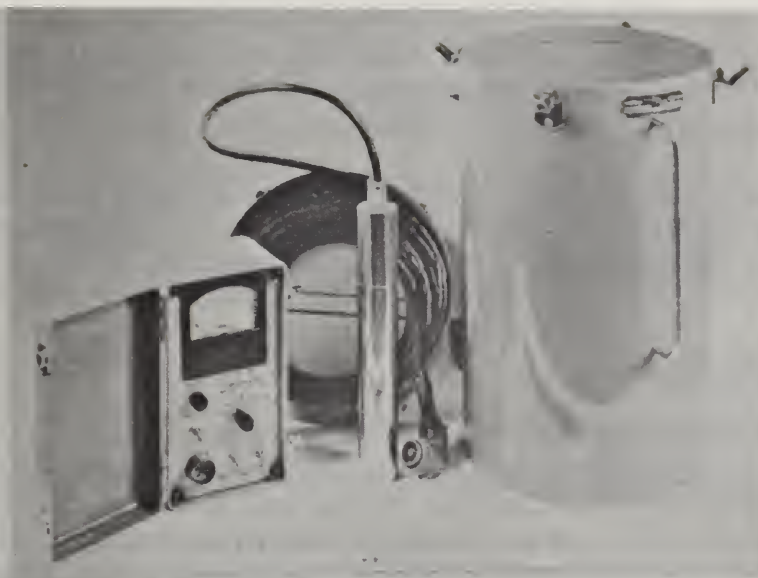
To measure soil moisture in mountain soils, some kind of equipment that provides an indirect measurement is used. It is not practical to take soil samples under the snowpack. It must be possible to measure a wide range of soil temperature and moisture.

Both electrical resistance units and neutron probes give reasonably satisfactory results. Electrical resistance units are reasonable in cost, simple in construction, and dependable in operation. They also have an element for obtaining soil temperature readings and can be adapted for reading by remote telemetry systems. Neutron and resistance meters are shown in figure 2-23.

The neutron system may be more economical for networks of closely spaced data sites. One scaler can be used for any number of stations. The neutron system is more accurate, particularly when soil moisture changes rapidly.

Site Selection

The site should be typical of the watershed in slope, soil cover, and exposure for the elevation selected. Rock outcrops, wet spots, or steep slopes should be avoided.



Neutron Scaler, Probe and Container
(Kaiser Aircraft and Electronics)

Bouyoucos Meter
(Industrial Instruments Inc.)

Coleman Meter
(Electrodyne Inc.)

BN-38793

Figure 2-23.--Typical neutron and resistance meters.

The seasonal variation in soil moisture at the site should be 4 or more inches, and the total water-holding capacity of the soil profile being measured should exceed 7 inches. Seasonal snowfall should have an equivalent of 10 or more inches of water.

If these conditions can be met, it is best to have the soil moisture station on a snow course. If it is located nearby, the exposure and cover on the soil moisture station should be similar to that for the snow course.

Mapping and Marking

If the soil moisture station is on or near a snow course, its location should be marked by placing a small triangle on the snow course map. The label "Soil Moisture Station" is to be indicated on the map. If the station is not on a snow course, a map similar to a snow course map should be prepared that shows the terrain features, area location, and the station number (see fig. 2-2).

Soil moisture stations carry the name of the snow course on which they are located or if within 500 feet. Soil moisture stations are numbered, e.g., those on a snow course, 17G17M, and separate stations, 17G17m. See the snow course number system outlined in chapter 5.

Temperature corrections for the individual units are shown on the map as well as on the soil moisture station biography form (fig. 2-24).

Colman and Bouyoucos Resistance Units

Description

Since the resistance of the porous material between the unit electrodes varies with the amount of moisture, change in resistance is used as a measurement of soil moisture. The material is selected so its moisture content is representative of the moisture in the surrounding soil.

Resistance units use either fiberglass mesh or nylon-reinforced gypsum moisture-holding material. Most soil moisture installations are of fiberglass (Colman units). Wires are connected to two Monel metal electrodes that are wrapped in fiberglass cloth and encased in Monel metal. On units that include a temperature sensor, a red wire is connected to the moisture-equivalent electrode and a white wire to the temperature element, and a black wire serves as a common or ground connection to the red and white wires. The resistance range for moisture is about 1,000 ohms at field capacity and about 250,000 ohms at wilting point. The unit also has a wire connected to a thermistor. Temperature readings cover the range from about 0° to 100° F.

The gypsum or Bouyoucos block units consist of two electrodes imbedded in nylon-reinforced gypsum. The resistance ranges from about 400 ohms at field capacity to about 100,000 ohms at wilting point. The units are designed to operate best in the upper two-thirds of the available soil

UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service

SOIL MOISTURE STATION BIOGRAPHY

Station No. and Name 21D25M Cooper Spur Sec. 6 Twp. 2S Range 10E

Lat. 45°26' Long. 121°36' Elev. 3490' Aspect(facing) East

Exposure(include base vegetation) Fir (closed) Approx. Slope 2%

Date Established October 1967 Related Snow Course Cooper Spur

Detailed Location and Route: As noted on Snow Course Map for the related snow course.

Land Owner: U.S. Forest Service

Units and Soils Description

Unit No.	Depth	Lot	Corr. Coef.	Soil Cap.(in.)		Soil Description(General)
1	6"		0.96	4.19	0"-12"	Very fine sandy loam
2	20"		1.01	4.57	12"-24"	Fine sandy loam
3	30"		1.02	4.81	24"-36"	" " "
4	42"		1.03	4.58	36"-48"	Stony fine sandy loam
5	54"		1.03	4.14	48"-60"	" " " "
6	66"		0.95	4.15	60"-72"	" " " "

Notes on Soil Tests:

Sketch of wire identification: (show if it varies from standard)

Standard ID

Oregon	Oct. 1967	W. T. Frost
State	Date	Snow Survey Supervisor

Figure 2-24.--Soil moisture station biography form.

moisture range, which limits their usefulness to some degree. There is some evidence that gypsum units do not operate in soil for an extended period of time. The Colman unit, on the other hand, has a long life. Additional description of the units and their operating characteristics can be obtained from the respective manufacturers. (1)

Installation

For water supply forecasting, the units are placed at intervals (vertical) of 6 or 12 inches in the soil to a depth of 3 feet at a minimum, 4 or 5 feet typically, and 6 feet at a maximum.

The sites generally are on slopes of less than 15 percent. The uphill face and sides of the pit dug into the soil must be vertical. In most places the bottom 1 or 2 feet can be dug with a post-hole digger. After the pit is dug, the units are placed 2 to 6 inches into undisturbed soil in the uphill face. The holes for Colman units can be made with a broad-blade knife or similar tool. The sides of the unit should be in close contact with the soil. The lead wires are dressed downward for a short distance to avoid drainage to the unit.

After the bottom unit is placed, the pit is filled and packed to the level of the next higher unit. To refill the pit, the soil used for each unit is from the same layer as that of the undisturbed soil. Successively higher units are placed in a similar manner. Units in the upper foot are placed after the vertical pipe has been set in concrete or placed permanently (see fig. 2-25 for a sketch of a typical installation of resistance units).

The pipe, 2 inches in diameter, should be long enough to reach above the snowpack at its maximum depth. It should be placed about 3 feet from the units and to a depth of 2 to 3 feet in the soil, depending on the height of the pipe. A 90-degree elbow and 6 or more inches of pipe should be placed on the horizontal in the soil to protect the unit wires and to help support the vertical pipe. One cubic foot of concrete around the vertical pipe is adequate, and wires must not be embedded in the concrete.

A 6-inch nipple and a cap are used at the top of the pipe to hold the terminal strip for the wires. The terminal strip is held in the upper section of the pipe by a wood, rubber, or plastic plug that fits into the coupling. A typical terminal strip also is shown in figure 2-25. Common (ground) wires from all units should be brought to one connecting point. The other leads for soil moisture and temperature are connected to terminals near the sides of the strip. Terminal strip connections and any splices made in the wires should be soldered. Avoid splices but, if necessary, use electrical tape to prevent grounding of the leads. The top unit is connected to the top points on the strip and lower units are connected in sequence.

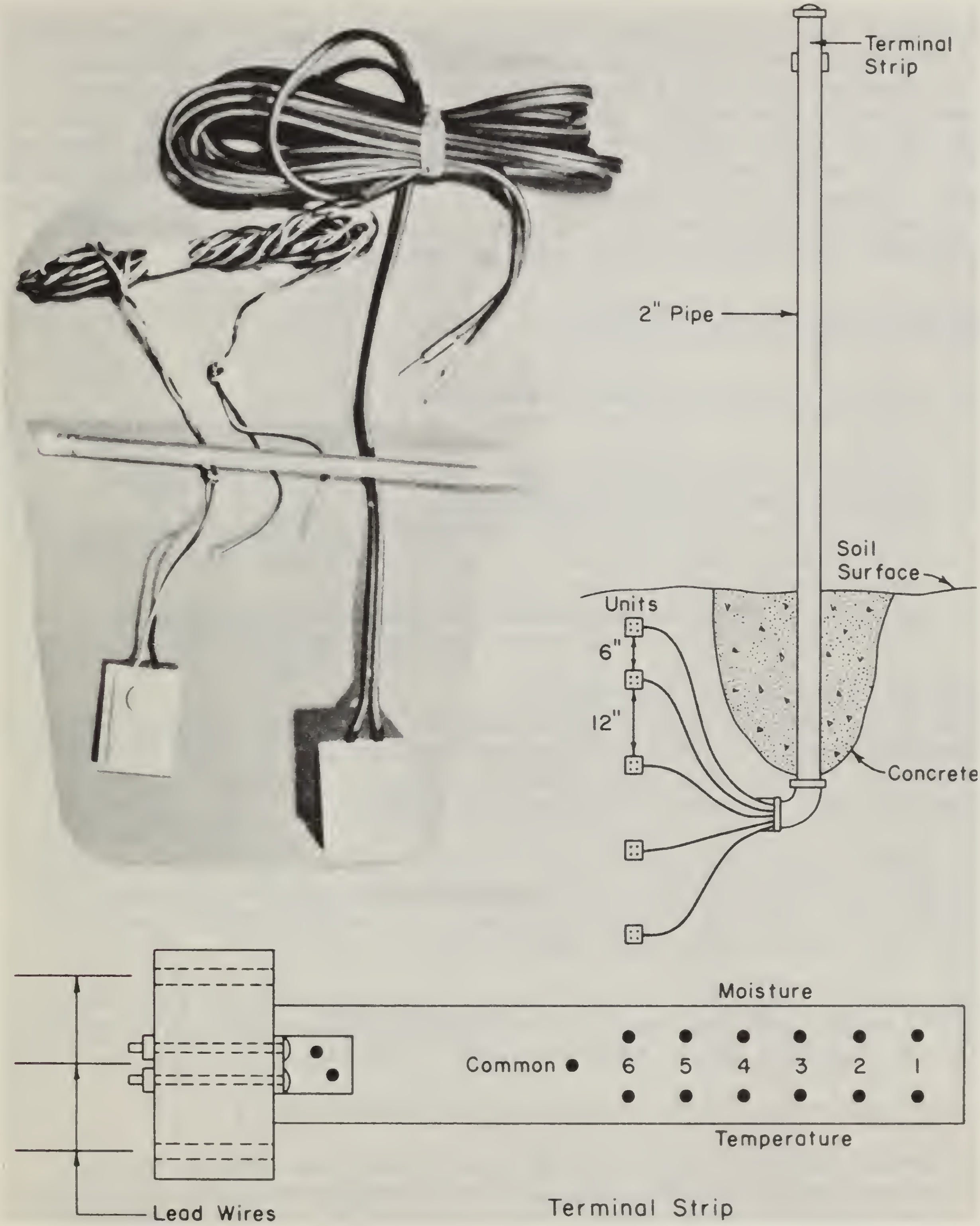


Figure 2-25.--Colman and Bouyoucos blocks (upper left), soil moisture station installation (upper right), and terminal strip (lower).

The units should be checked for proper operation before they are taken to the field. Each unit should be wet in distilled water preferably or in tap water usually and then wiped dry. The wet Colman units should have a resistance between 400 and 1,500 ohms and Bouyoucos units between 200 and 600 ohms; units outside this range should not be used. Standards for other units are not available for use in this handbook. The temperature reading should be checked (1,000 ± 100 ohms at 77° F.). Immediately before installation the units should be checked again to determine if they have been damaged in transport or during installation.

Recording Data on Installation

The following data are recorded:

1. Depth of the units below ground surface.
2. Lot number and temperature correction for each unit identified by depth.
3. Location of the unit stack with reference to the standpipe.
4. Wiring diagram of the terminal strip.
5. Description of soil and depth of layers (e.g., Forest duff 0 to 2 inches, black sandy loam 2 to 20 inches, gravelly loam 20 to 32 inches, gravel and boulders 32 to 48 inches).
6. Estimate of water-holding capacity represented by each unit.
7. Soil moisture station biography form (see fig. 2-24) is completed.

Reading and Recording Observations

Because of possible variations in terminal strips and different kinds of ohmmeters, observers of soil moisture stations should check for peculiarities in installation and ohmmeter readings. The following general comments apply to most installations and meters.

The meter scale readings obtained for soil moisture and temperature are recorded on form SCS-ENG-707 (rev. 6/69), Soil Moisture Surveys. Completed forms for soil moisture readings are shown in figure 2-26 for resistance and neutron probe installations.

Temperature indexes are always read on the low scale (low resistance) of the meter. Soil moisture is read on both high and low scales except for the Bouyoucos meter, which has only a low scale.

To get measurements of soil moisture and temperature,

1. Attach moisture lead (red) and temperature lead (white) to the corresponding terminal points on the terminal strip for the first or top unit and the common lead (black) to the common (negative) terminal point.
2. Turn meter switch to "on." On meters that have vacuum tubes, a short time with the switch turned to "fil" allows the tube to warm.
3. Turn the adjust-read switch to adjust and the high-low switch to low. Turn the adjust knob on the meter scale to the calibration index (on Colman and Montronics meters the calibration index reading is 200). The calibration index is the maximum scale reading.

SCS-ENG-707
(rev. 6-69)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Federal and State Cooperative Snow Surveys

SOIL MOISTURE SURVEYS

Soil Moisture Station Ward Creek

State Nevada Drainage Basin Tahoe

Observer Jones - Smith

Date 3/1/66 Meter adj. to 200

Meter Type Colman Unit Type Colman (Resistance)

UNIT NO. OR DEPTH	DIAL READING: TEMP. Low Scale	DIAL READING: MOISTURE High Scale	DIAL READING: MOISTURE Low Scale	SOIL TEMP. °F.	SOIL MOISTURE INDEX	TOTAL ~~AVAILABLE~~ MOISTURE INCHES
6"	95	10		28	.60E	0.9
12"	102		82	32	70	1.1
24"	101		96	32	74	2.2
36"	102		125	33	86	2.6
48"	105		140	34	93	1.9
				completed	in office	
					TOTAL	8.7

REMARKS:
Top 6" Frozen - Moisture Estimated

(Interpretation based on Top 3' - medium soil ; Bottom Foot - sandy soil)

COLEMAN ADJUSTED TO 200
BOUYOUCOS ADJUSTED TO ZERO INDEX

NO. 1 OF 1 SHEETS COMPILED BY ABC CHECKED BY DEF

GPO 16—67961-2

SCS-ENG-707
(rev. 6-69)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Federal and State Cooperative Snow Surveys

SOIL MOISTURE SURVEYS

Soil Moisture Station Beaver Creek- Skunk Creek

State Utah Drainage Basin Ogden River

Observer G. Dinsdale

Date 2/28/65 Meter adj. to Average Calibration - 6114

Meter Type Nuc - chic Unit Type Nuclear - Chicago

UNIT NO. OR DEPTH	DIAL READING: TEMP. Low Scale	DIAL READING: MOISTURE High Scale	DIAL READING: Count Ratio	SOIL TEMP. °F.	SOIL MOISTURE INDEX 90	Total ~~AVAILABLE~~ MOISTURE INCHES
Calibration		6171				
6"		7582	1.240		37	2.22
12"		5293	0.865		31.5	1.89
18"		5127	0.838		30.5	1.83
24"		5782	0.946		34	2.04
30"		6078	0.994		36	2.16
36"		5586	0.914		33	1.98
42"		4923	0.805		29.5	1.77
48"		4513	0.738		27	1.62
Calibration		6057				
					TOTAL	15.51

REMARKS:

NeuTron Readings

COLEMAN ADJUSTED TO 200
BOUYOUCOS ADJUSTED TO ZERO INDEX

NO. 1 OF 1 SHEETS COMPILED BY G.D. CHECKED BY J.L.P.

GPO 16—67961-2

Figure 2-26.--Completed soil moisture notes--resistance and neutron.

4. Turn the moisture-temperature switch to temperature. Turn the adjust-read switch to read. Observe and record the meter reading for temperature under the No. 1 unit.
5. Turn the moisture-temperature switch to moisture. If the reading is in the middle 75 percent of the scale (30-175), observe and record the reading under the moisture low scale. If the reading is outside this range, turn to "Hi" scale, calibrate index the meter, obtain the reading, and record it under moisture high scale.
6. Change the leads to moisture and temperature on the second, third, fourth, etc. units from the top and repeat the procedure. Turn the meter off at the conclusion of all readings.

If a reading is in the upper 10 to 15 percent (above 180) of the low scale, the unit may be shorted or there may be excessive free water at the location. If a reading is below the lower 10 to 15 percent on the high scale (below 30), the soil is extremely dry or frozen or there may be an open circuit. A reading in the lower 5 percent on the high scale (below 10) is a definite indication of frozen soil or an open circuit. All seemingly defective readings should be recorded and noted.

Sometimes it is impossible to obtain a zero index at the proper index point because of weak batteries or extremely cold air temperatures, or both. If this occurs, a calibration index of less than the maximum scale should be selected and noted, e.g., 170 instead of 200. Record readings as observed.

Interpretation

On Bouyoucos block installations, the percentage of soil moisture by weight is read directly on the meter. It is necessary to know the total water-holding capacity of the depth of soil represented by the unit.

The temperature scale for Colman units is taken directly from the resistance reading on the thermistor. Standard temperature charts can be made from the manufacturer's literature. The milliamp reading-resistance curve comes with the meter. The following resistance readings (in ohms) are standard for the temperatures usually experienced.

°F.	Resistance in ohms	°F.	Resistance in ohms
30	3,500	36	2,900
31	3,400	37	2,800
32	3,300	38	2,700
33	3,200	39	2,700
34	3,100	40	2,600
35	3,000	41	2,500

Individual units need to be corrected for temperature readings. Correction factors are stamped in the metal of each unit. A table of corrections for variations in units follows.

Correction factor	Correction for °F.
0.90-0.92	+3
0.93-0.95	+2
0.96-0.98	+1
0.99-1.01	0
1.02-1.04	-1
1.05-1.06	-2
1.07-1.10	-3

Converting a meter reading to total soil moisture in inches on Colman units is, to some degree, empirical. Although extensive field and laboratory tests can be devised to increase accuracy of the relationship, they are time-consuming. There is considerable question that the extra effort will produce a more usable index for improving water supply forecast accuracy.

There are two general approaches for improving this relationship:

1. Take samples of soil from the proposed location, place them between pressure plates with the units that are to be used embedded in the sample. Then take five or more readings over a pressure range of one-third atmosphere to 15 atmospheres. Instructions on this technique can be obtained from soil laboratories at state universities.
2. Install a neutron counter station next to the resistance station and obtain five or more concurrent readings distributed over a range from wilting point to field capacity. This approach, however, is time-consuming, and calibration may require several years.

Using the standard calibrations listed in table 2-2 provides a practical interpretation procedure. Should field-meter readings be made with a calibration index of less than 200 on the Colman meter, the reading is increased in proportion to the amount represented by the difference between 200 and the index reading actually obtained.

Neutron Probes

Description

A fast neutron source is used in measuring soil moisture. Hydrogen atoms have the property of slowing down fast neutrons when they collide. Since the detector in the probe measures only the neutrons that were slowed down by water in the soil, it provides an empirical measure of soil moisture. The slowed neutrons that are counted are proportional to the amount of water in the sphere of influence of the source of radioactivity.

Table 2-2.--Standard conversion table--meter readings to inches of soil moisture

Bouyoucos	Montronics		Colman	Resistance	Total soil moisture	Water per foot
	Meter readings			Ohms	Percent	Inches
			Sandy soils			
	Old	New				
96	142L	142L	175L	500	110	2.2
72	104L	106L	154L	1,000	100	2.0
64	90L	92L	144L	1,300	90	1.8
57	73L	75L	130L	1,800	80	1.6
50	60L	62L	115L	2,400	70	1.4
40	40L	42L	92L	3,900	60	1.2
24	187H	187H	44L	11,000	50	1.0
15	78H	78H	66H	67,000	40	0.8
--	29H	30H	24H	220,000	30	0.6
--	10H	12H	10H	600,000	20	0.4
			Medium soils			
96	142L	144L	175L	500	110	3.3
72	104L	108L	154L	1,000	100	3.0
60	83L	86L	138L	1,500	90	2.7
50	60L	63L	115L	2,400	80	2.4
36	35L	38L	82L	4,700	70	2.1
16	150H	153H	136H	21,000	60	1.8
--	96H	99H	81H	49,000	50	1.5
--	55H	58H	46H	105,000	40	1.2
--	5H	9H	6H	1,000,000	30	0.9
			Silts and clays			
96	142L	144L	175L	500	110	4.4
72	104L	108L	154L	1,000	100	4.0
55	70L	72L	127L	1,900	90	3.6
40	40L	43L	92L	3,900	80	3.2
18	160H	162H	146H	18,000	70	2.8
--	112H	115H	96H	38,000	60	2.4
--	82H	84H	68H	63,000	50	2.0
--	48H	52H	38H	125,000	40	1.8

NOTE: Maximum readings obtained 400 to 1,500 ohms. Colman units 33° F. L = low scale; H = high scale.

When not in use, the probe is kept in a calibrating container that also acts as a shield against the radioactive source. Water and silica gel make up the nonmetallic part of the shield. The silica gel contains a fixed percentage of water by volume (25 percent). To determine the amount of water in the soil in percentage by volume, the neutron count obtained in the soil is divided by the count in the calibrating container multiplied by the standard percentage of water. Further details can be obtained from manufacturers.(2)

Installation

Sites for soil moisture installations using a neutron probe are the same as for resistance units. Field installation for a neutron probe consists of placing a steel or aluminum pipe vertically in the soil. The diameter of the pipe used depends on the diameter of the probe. Since the pipe should be watertight, the bottom is closed. The pipe extends a few inches above the ground and is capped. Before each snow season a coupling and additional length of pipe are attached to allow access from above the snowpack.

Where there are no rocks, the holes for the pipe can be dug with a soil auger, the pipe placed to the proper depth (minimum 3-1/2 feet to allow for centering the probe in the middle of the 3-foot level), and the space around the pipe carefully refilled and packed. The soil for refilling should be from the same layers removed from the soil.

If it is necessary to dig a pit, the procedure is similar to that for resistance units. The pipe is placed in a formed space in the uphill face of the pit so that the pipe can be placed against undisturbed soil.

Recording Data on Installation

The following data are recorded:

1. Description of soil and depth of layers (e.g., Forest duff 0 to 2 inches, black sandy loam 2 to 20 inches, gravelly loam 20 to 32 inches, gravel and boulders 32 to 48 inches).
2. Estimate of water-holding capacity of each soil layer.
3. Distance from the bottom of the pipe to the top of the ground.
4. Length of any additional sections needed to reach above the maximum expected snow depth at the site.
5. Soil moisture station biography form (fig. 2-24) is completed.

Reading and Recording Observations

The neutron reading unit consists of scales, probe, probe-calibration container, cable from the probe to the scales, and a stopwatch. The cable is marked in feet from the center of the probe. An observer must know the number of feet or inches from the top of the access pipe to the points of measurement.

The probe should be carried in the calibration container when it is not used for observations. Temperature readings are not made. These general steps are taken in measuring soil moisture:

1. Connect probe to scales with a cable.
2. Turn on the scales with the probe in the calibration container.
3. Turn on stopwatch and scales meter simultaneously. Operate for 1 minute and turn them off simultaneously. Record the count on the meter dials (digital) under "Calibration" as shown on the first line of the sample notes (fig. 2-26). This is the calibration for a standard soil moisture reading (such as 25 percent by volume or 3 inches per foot). If there is snow in the vicinity, the probe and container should be at least 2 feet from the snowpack during the calibration reading. It is best to do this calibration in a vehicle. Some meters have rate readouts; on these meters, using a stopwatch is not necessary.
4. Remove pipe cover. Lower a tape or some similar item into the pipe. If necessary, lower a silica gel container to absorb any moisture. Remove probe from container and lower it into the pipe until it reaches bottom. Turn on scales and meter and take a 1-minute count. Record the lowest depth reading for the site under "Moisture High Scale."
5. Raise probe to the next level and repeat reading. Readings are usually taken at 1-foot intervals. After all the readings are taken, make a final calibration check and return the probe to the container. Record calibration reading as shown on the last line of the sample notes. Average the beginning and ending calibration readings and record on top of the form under "Meter adj. to." The readings should not differ much from those of the calibration container, and in most cases they should be lower. Readings in the top foot exceeding those of the calibration container should be questioned since they probably include moisture in the snowpack.

Interpretation

Neutron probes are designed to measure directly the volume of soil moisture, which is determined by the following steps. Obtain the count ratio by dividing the reading at each depth level by the average of the two calibration readings. Use the standard calibration curve for the particular instrument to obtain the percentage of soil moisture by volume. To obtain soil moisture content in inches, multiply the soil-moisture percentage by the number of inches that the reading represents, usually 6 or 12 inches of soil. In the sample notes shown in figure 2-26, the soil depth increment is 6 inches.

Forest Cover

Forest cover is a significant factor in snow accumulation and melt at a snow course. Therefore, any change in forest cover may gradually affect the readings obtained over a period of years. Various instruments and methods have been developed to determine forest cover. A canopyometer,

which provides a record on film for future observation and analyzing, is recommended.

Measuring Forest Cover

A canopyometer is a modification of a folding camera using 120, 620 film or one producing a 2-1/4- by 2-1/4-inch negative. A pinhole plate is substituted for the lens and adjusted to produce a 90° angle of view. The camera must have a flat back parallel to the film plane. If the camera is placed on its back with the pinhole pointed skyward, a photograph can be obtained that shows the canopy within the 45° cone angle. To maintain a standard for future canopyometer measurements, the camera is generally oriented true north and leveled. A tripod with a special ball and socket head is used for support, and a cable release prevents movement during exposure. One exposure is made at each snow sampling point, soil moisture station, or precipitation gage.

Recording Data

An accurate record that shows the location of each exposure is most important. The film is developed in the usual manner, and the location number, date taken, and sample point are printed on each negative. The negative is sandwiched with a dot planimeter transparent grid, and the resultant print shows where and when the exposure was made, north arrow, canopy at that point, dot planimeter, and the 15°, 30°, and 45° circles. The dot count can be converted to percentage cover from a conversion table.

Changes in snow accumulation index can be related to changes in canopy cover. The canopy cover outside the 30° cone has little effect on snowpacks and does not affect melt. Comparing the percentage of canopy cover with individual snow measurements on a snow course shows the relation between canopy and accumulation. The measurements can be adjusted to compensate for changes in canopy cover, thus improving forecasting accuracy. Canopy measurements taken about every 5 years record any change in forest canopy caused by insect infestation, fire, logging, or tree growth. If fire, logging, or insect infestation change the canopy at an index site, the relation between snow measurements and runoff is changed. A record of canopy changes makes it possible to correct the records.

Figure 2-27 shows a canopy with an overlay of the dot grid and other information. Figure 2-28 shows the computation form used to calculate and record canopy data, while table 2-3 gives the tables prepared to compute the percentage of canopy covered in the 15°, 30°, and 45° zones.

Figure 2-27.--Print from canopy negative with overlay of dot grid used to determine canopy cover.

CANOPY COVER MEASUREMENT (Rev. 9/66)

SNOW SURVEY COURSE West Yellowstone NUMBER 11E07

OBSERVER George Clagett DATE 8/5/70 ELEV. 6700

Sample Point Number	Sector and ¼ Annulus	Dot Count By Sector and ¼ Annulus				Total Dot Count	Accm. Total	Percent Canopy Cover		
		N E	N W	S W	S E			0° to 15°	0° to 30°	0° to 45°
1	0 to 15									
	15 to 30									
	30 to 45									
	Totals									
2	0 to 15									
	15 to 30									
	30 to 45									
	Totals									
3	0 to 15									
	15 to 30									
	30 to 45									
	Totals									
4	0 to 15	0	0	0	0	0	0			
	15 to 30	7	2	9	4	22	22			
	30 to 45	47	22	38	32	139	161	0	19.6	48.5
	Totals	54	24	47	36	161				
5	0 to 15									
	15 to 30									
	30 to 45									
	Totals									
6	0 to 15									
	15 to 30									
	30 to 45									
	Totals									
7	0 to 15									
	15 to 30									
	30 to 45									
	Totals									
8	0 to 15									
	15 to 30									
	30 to 45									
	Totals									

Computed By G. C. Date 10/8/70 No.

Checked By P. F. Date 10/8/70

Total			
Points			
Average			

Figure 2-28.--Computation form for recording canopy data.

Table 2-3.--Tables for computing percentage canopy covered

0 - 30° 112 Dots

Percent Canopy For Number of Dots Covered

	0	1	2	3	4	5	6	7	8	9
0	0	0.9	1.8	2.7	3.6	4.5	5.4	6.2	7.1	8.0
1	8.9	9.8	10.7	11.6	12.5	13.4	14.3	15.2	16.1	17.0
2	17.9	18.8	19.6	20.5	21.4	22.3	23.2	24.1	25.0	25.9
3	26.8	27.7	28.6	29.5	30.4	31.2	32.1	33.0	33.9	34.8
4	35.7	36.6	37.5	38.4	39.3	40.2	41.1	42.0	42.9	43.8
5	44.6	45.5	46.4	47.3	48.2	49.1	50.0	50.9	51.8	52.7
6	53.6	54.5	55.4	56.2	57.1	58.0	58.9	59.8	60.7	61.6
7	62.5	63.4	64.3	65.2	66.1	67.0	67.9	68.8	69.6	70.5
8	71.4	72.3	73.2	74.1	75.0	75.9	76.8	77.7	78.6	79.5
9	80.4	81.2	82.1	83.0	83.9	84.8	85.7	86.6	87.5	88.4
10	89.3	90.2	91.1	92.0	92.9	93.8	94.6	95.5	96.4	97.3
11	98.2	99.1	100.0							

0 - 15° 24 Dots

Percent Canopy For Number of Dots Covered

	0	1	2	3	4	5	6	7	8	9
0	0	4.2	8.3	12.5	16.7	20.8	25.0	29.2	33.3	37.5
1	41.7	45.8	50.0	54.2	58.3	62.5	66.7	70.8	75.0	79.2
2	83.3	87.5	91.7	95.8	100.0					

0 - 45° 332 Dots

Percent Canopy For Number of Dots Covered

	0	1	2	3	4	5	6	7	8	9
0	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7
10	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7
20	6.0	6.3	6.6	6.9	7.2	7.5	7.8	8.1	8.4	8.7
30	9.0	9.3	9.6	9.9	10.2	10.5	10.8	11.1	11.4	11.8
40	12.0	12.4	12.6	13.0	13.2	13.6	14.9	14.2	14.5	14.8
50	15.1	15.4	15.7	16.0	16.3	16.6	16.9	17.2	17.5	17.8
60	18.1	18.4	18.7	19.0	19.3	19.6	19.9	20.2	20.5	20.8
70	21.1	21.4	21.7	22.0	22.3	22.6	22.9	23.2	23.5	23.8
80	24.1	24.4	24.7	25.0	25.3	25.6	25.9	26.2	26.5	26.8
90	27.1	27.4	27.7	28.0	28.3	28.6	28.9	29.2	29.5	29.8
100	30.1	30.4	30.7	31.0	31.3	31.6	31.9	32.2	32.5	32.8
10	33.1	33.4	33.7	34.0	34.3	34.6	34.9	35.2	35.5	35.8
20	36.1	36.4	36.7	37.0	37.3	37.6	38.0	38.2	38.6	38.8
30	39.2	39.5	39.8	40.1	40.4	40.7	41.0	41.3	41.6	41.9
40	42.2	42.5	42.8	43.1	43.4	43.7	44.0	44.3	44.6	44.9
50	45.2	45.5	45.8	46.1	46.4	46.7	47.0	47.3	47.6	47.9
60	48.2	48.5	48.8	49.1	49.4	49.7	50.0	50.3	50.6	50.9
70	51.2	51.5	51.8	52.1	52.4	52.7	53.0	53.3	53.6	53.9
80	54.2	54.5	54.8	55.1	55.4	55.7	56.0	56.3	56.6	56.9
90	57.2	57.5	57.8	58.1	58.4	58.7	59.0	59.3	59.6	59.9
200	60.2	60.5	60.8	61.1	61.4	61.8	62.0	62.4	62.6	63.0
10	63.2	63.6	63.8	64.2	64.5	64.8	65.1	65.4	65.7	66.0
20	66.3	66.6	66.9	67.2	67.5	67.8	68.1	68.4	68.7	69.0
30	69.3	69.6	69.9	70.2	70.5	70.8	71.1	71.4	71.7	72.0
40	72.3	72.6	72.9	73.2	73.5	73.8	74.1	74.4	74.7	75.0
50	75.3	75.6	75.9	76.2	76.5	76.8	77.1	77.4	77.7	78.0
60	78.3	78.6	78.9	79.2	79.5	79.8	80.1	80.4	80.7	81.0
70	81.3	81.6	81.9	82.2	82.5	82.8	83.1	83.4	83.7	84.0
80	84.3	84.6	84.9	85.2	85.5	85.8	86.1	86.4	86.7	87.0
90	87.4	87.6	88.0	88.2	88.6	88.8	89.2	89.5	89.8	90.1
300	90.4	90.7	91.0	91.3	91.6	91.9	92.2	92.5	92.8	93.1
10	93.4	93.7	93.8	94.3	94.6	94.9	95.2	95.5	95.8	96.1
20	96.4	96.7	97.0	97.3	97.6	97.9	98.2	98.5	98.8	99.1
30	99.4	99.7	100.0							

Evaporation Parameters

Use in Forecasting

Throughout the Rocky Mountain region there are thousands of square miles of alpine and subalpine terrain. Snow courses can provide reliable indexes of the water content of snow in storage in the forested areas of the mountain, but determining the water in storage in the alpine snowpack is more difficult. In some years heavy wind, high temperatures, and intense solar radiation reduce the indicated water content of the alpine pack much below that measured at the snow courses protected by forest. Under these conditions certain parameters--wind flow, solar radiation, air temperature, and humidity--can be used to refine forecasts. A method for analyzing the evaporation parameters is given in chapter 6.

Difficulty in Collecting Data

Data on wind, solar radiation, temperature, and humidity at high elevations and on the relation of these factors to evaporation or sublimation of the snowpack in alpine regions are extremely scarce. The terrain and severe climatic conditions at the high elevations make collecting data difficult. Moreover, instruments normally used for weather observations are not satisfactory for mountain installations.

Adequate collection of such data must be done by remote sensors and radio telemetry networks. It is not feasible or possible in most instances to obtain data manually and as often as needed for keeping current on mountain conditions. Thus, commercially available instruments must be adapted or suitable instruments must be developed for sensoring devices to provide information in a form compatible with electronic telemetry hardware.

Measuring Parameters

Wind Flow and Direction

Wind flow and direction data are collected with an anemometer and a wind-direction indicator. Many instruments of a wide variety of design and make are available. For example, the readout of the anemometer may be provided by an electric contact mechanism that counts the number of contacts. Each contact represents a particular distance in units of a mile. Speed indicators may use a wind-powered generator. The generator output in volts is proportional to wind speed. Wind direction is determined by observing the orientation of a wind vane or is observed remotely on an indicator with a compass dial or light indicators. A wind vane and anemometer may be combined in one instrument to supply data on wind flow and direction. Chart recorders can be connected to the instruments for a continuous record of wind flow and direction.

Most or all of the commercially available components have to be altered to meet mountain conditions, including the power source. Also, the outputs of these instruments must be suitable for connection to telemetry equipment.

Winds-aloft data are collected by tracking meteorological balloons with a theodolite or with radar and radiosonde equipment. Readings give upper-air wind direction and speed.

Solar Radiation

The solar radiation intensity is measured in Langleys (1 Langley equals 1 cal/cm^2 min.) and also in Btu's per square foot per hour. Instruments of several makes and designs are available for measuring radiation. Some use the silicon photo voltaic cell as the sensor, and some provide an instantaneous milliampere reading or an integrating ampere-hour meter digital readout. The power output of the cells is proportional to the radiation intensity. Some instruments are protected by glass covers or domes. Most commercially available instruments are not suited to mountain installation since their covers ice over or condensation freezes inside, affecting the readings.

The telemetry of information depends on an instrument and encoding device designed to permit connection to a telemetry system.

Temperature

A thermistor is a device in which electrical resistance changes with temperature. Therefore, it can be used to measure air and soil temperatures. Electrical resistance can be encoded for telemetry purposes.

A thermocouple or bimetallic temperature sensor produces mechanical movement proportional to temperature changes. This device, in suitable configuration, can be linked to an iron slug to produce inductance changes in a coil, thus permitting telemetry of temperature values.

As in other sensoring devices, the range of change in resistance, inductance, and capacitance must be within limits suitable for modulating the radio transmitting equipment. Coded data can be transmitted in analog or digital form.

Humidity

In a hygrometer the hygroscopic animal membrane responds to changes in relative humidity, which are expressed in percent. A mechanical linkage is used to give dial readings or to operate the pen arm for chart recorders.

A hygrothermograph is a dual-purpose device that provides a chart recording of temperature and relative humidity. Most instruments use human hair for the humidity element and a bimetallic strip for temperature.

Commercially available equipment suitable for mountain operation must be developed or altered. The mechanical movement in this type of instrument can be used to change the inductance in coils, thereby permitting encoding of information for transmission.

Streamflow

Sources of Data

The U.S. Geological Survey collects most streamflow data and publishes them in its Water-Supply Papers.(3) Other federal, state, and private agencies collect some streamflow data for their operations, but frequently do not publish them. In some places SCS collects streamflow data or assists in installing streamflow measuring devices if there are no practical alternatives.

Measuring Streamflow

On smaller streams, the most accurate streamflow measurements are obtained by using a water-stage recorder on a Parshall flume or weir. On sections of streams having a straight, fairly regular cross section and a smooth bottom, good records can be obtained by using a water-stage recorder and by rating the channel with a current meter. This method is used extensively by the U.S. Geological Survey. Records also can be obtained by observing a staff gage daily and by rating the channel with a current meter. This method is not recommended because daily variation in flow can be very large during snowmelt and flood flows resulting in inaccurate measurements. During recession, daily staff observations can result in fairly accurate records since daily variations are usually small.

Current-meter measurements should be taken where the stream is straight and has a fairly uniform cross section that is not affected by backwater. A stable channel and good downstream control provide a more accurate rating curve.

If the stream is too deep or swift to be waded during high water, an existing bridge should be used to obtain current-meter readings. Construction of a cable-car system or bridge is expensive, but sometimes is the only feasible way to obtain the required flow readings.

References

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2. Nuclear Chicago, Evanston, Ill.; Troxler Laboratories, Raleigh, N.C., and Kaiser Aircraft and Electronics, Phoenix, Ariz.

3. U.S. Geological Survey. 1943. Stream Gaging Procedure. Water-Supply Paper 888. U.S. Government Printing Office, Washington, D.C. 20402. 245 pp.

CHAPTER 3. TELEMETRY IN DATA COLLECTION

CONTENTS

Figure

CHAPTER 3. TELEMETRY IN DATA COLLECTION

System

In snow surveys a telemetry system consists of one or more remote data collection sites, a repeater station, and a base station that receives and records mountain forecast data automatically or on demand. Data from collection sites are transmitted through the repeater to the base station. A typical telemetry installation is shown in figure 3-1. To facilitate maintenance and data analysis by automatic data processing equipment, it is necessary to standardize equipment and the data readout and recording procedures.

Remote Data Collection Sites

Remote data collection sites are places on the mountain that provide information on water content of the snow, total precipitation, air temperature, soil temperature, soil moisture, wind flow, solar radiation, and other parameters related to water supply forecasting. Equipment can be placed at existing snow courses or at new sites (see fig. 3-2).

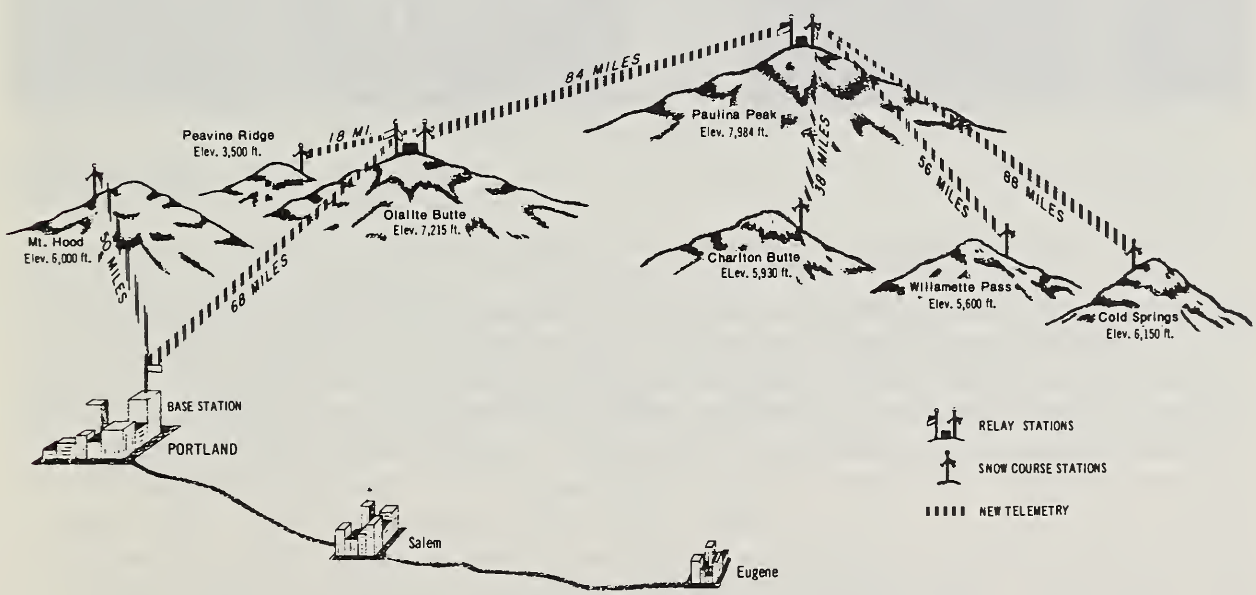

Figure 3-1.--Typical hydrometeorological telemetry network in mountains.

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Figure 3-2.--Automatic telemetry equipment at data collection site.

The equipment placed at data collection sites has several functions. Some components measure, weigh, and sense the information being collected. Other components convert weight, mechanical movement, or sensed information into suitable electronic values for electronic data transmission. The transmitter, receiver, antenna, and power supply receive signals from and transmit information to the base station. A pressure pillow is a device that indirectly weighs the snow. The pressure of the snow on the pillow operates other devices, both mechanical and electrical. The weight of precipitation in a rain or snow gage is used in the same manner. Thermistors in which resistance changes as temperature changes can be used to provide temperature readings. Other data collection components can be added, so long as the data outputs are compatible with the radio-transmitting equipment.

Repeater Station

A repeater station, usually on a prominent peak or mountain site, receives signals from the base station and passes them to the data site. Returning signals from the data site are passed on to the base station. In some places a repeater may not be needed; in others two repeaters may be required to obtain the areal coverage and span the distance from data sites to base station. Since the operating frequency in the VHF band requires a direct line-of-site radio path, it is generally necessary for the repeater station to "see" the antennas of both the base station and the data site. In most places the repeater station must serve or see more than one data site.

The usual equipment at the repeater site consists of the radio receiving and transmitting components, power supply, antenna, tower, and weatherproof housing. In most places AC power is not available from commercial sources, so there must be an onsite source. The thermal generator fueled by propane gas or solar cells in combination with nickel-cadmium batteries are the DC power sources used to run most field installations.

Base Station

This installation is usually located at an SCS work unit, area office, or state office, and its function is to interrogate the data sites, receive the information sent back, and make a record, which can be done by manual or automatic control. Several types of readouts--digital printer, teletype with punched paper tape, graph recording, and frequency count--are available, but a teletype modified to meet specific requirements is recommended.

The base station generally consists of the radio receiving and transmitting components, decoding circuits, and a teletype or other recording device (see fig. 3-3). A transmission line using an AC power source connects the antenna to the receiver and transmitter. Coded tones are used for "calling up" information from specific locations. Data sites normally report in sequence; a timing device permits the setting of reporting intervals.

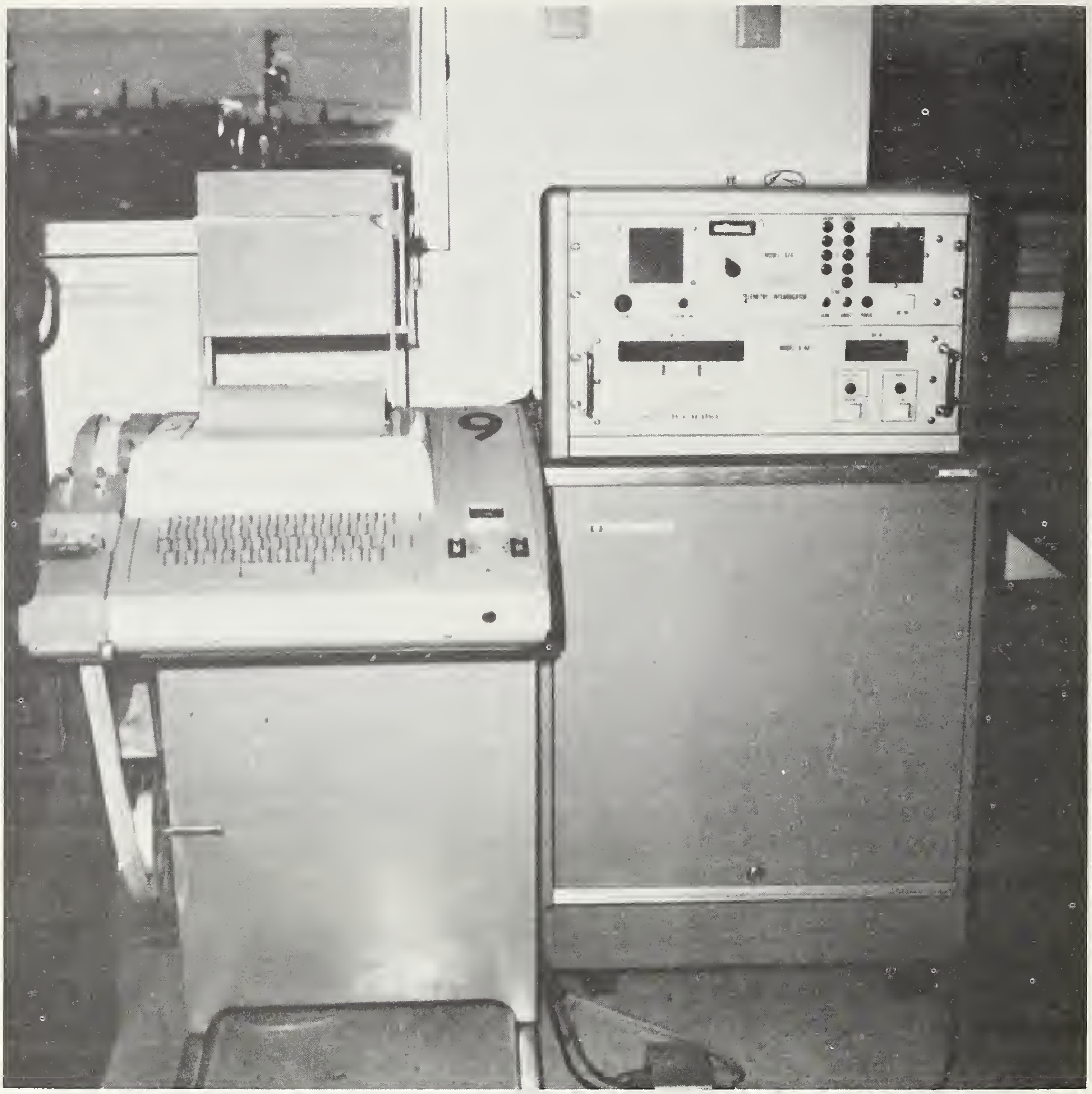

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Figure 3-3.--Base station: left, teletype machine; right, radio transmitting and receiving equipment.

Planning

Information that correlates highly with runoff must be available to make consistently accurate water supply forecasts. A data collection system is required, therefore, that can supply the kind and amount of information needed.

The snow course network and manual measurements of the snow courses and related factors provide a solid basis for making forecasts, but it is not always easy to explain variations of the forecast from actual measured flow. Generally, one or more factors have not been measured or considered in the forecast formula, and some forecasting errors are related to infrequent and inadequate sampling.

Telemetry systems can furnish data from mountains on any time basis and from sites not accessible by oversnow machine or on foot. Some balance between the number of stations measured manually and by telemetry is desirable. Automatic data collection at about 25 percent of the key snow courses will provide sufficient record for forecast purposes. Full instrumentation at a site to obtain data on water content of snow, precipitation, air and soil temperatures, soil moisture, wind movement, solar radiation, or other parameters likely to improve forecast accuracy should be considered.

Existing snow courses were located without considering possible future telemetry. Since the transmitting frequencies normally are in the VHF band, line-of-site paths must be available between data site and base station or between data site and a repeater. Therefore, in planning a segment of the network for telemetry, attention must be given to the location of the snow course, repeater, and base station. Some slight bending or bounce of radio waves is possible, but the signals may be erratic and attenuated. The best economy is achieved where a base station and repeater can interrogate and receive data from several outlying data sites. The repeater location must be selected with care since it must "see" the data collection sites as well as the base station.

The availability and cost of electronic equipment should be reviewed periodically to determine if collecting data from the entire network by telemetry is more economical than by manual procedures. The location of new snow courses, if possible, should be such that telemetry can be added.

Installation

Some logical plan should be followed in installing telemetry segments. It should indicate priorities for stations and describe how the full system will eventually operate. Administrative Services Memorandum-30 (rev. 4) dated November 29, 1971, explains how frequency and station authorizations are requested and assigned (fig. 9-2 shows a typical radio frequency and station authorization).

An actual field test must be made with portable two-way radios operating in the VHF or UHF band or in both bands to determine if radio signals can be transmitted with clarity and strength between points. Readings obtained with signal strength meters must be recorded.

Standard procedures are given in the Administrative Services Handbook for obtaining frequency and station authorizations and for negotiating contracts and issuing bid invitations in procuring equipment and installation services. Negotiated contracts generally are used if detailed specifications of components and associated circuits cannot be given. Since all sensors and telemetry components must be compatible and operate on a "turn key" basis, commercial components may not be available as shelf items. Invitation-to-bid procedures should be used if specific components and specifications can be stated and described. Negotiated contracts and bid procedures require 2 or 3 months. Moreover, delays may be experienced since snow and adverse weather conditions at high elevations limit the time during which networks can be installed to a few summer months.

CHAPTER 4. TRAVEL TO COLLECT DATA

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CHAPTER 4. TRAVEL TO COLLECT DATA

Trip Plan and Schedule

Even if the entire snow survey trip is by automobile on well-traveled roads, by oversnow machines, or by aircraft, each snow survey party must consist of at least two persons if there is a possibility of personal hazard. A party leader must be designated and must plan the trip in detail before departure. Avalanche paths, dangerous rivers, steep side slopes, and all other terrain barriers should be considered in the plan. If it is likely that an avalanche may delay the trip, an alternative plan should always be considered before departure.

The schedule of the trip including route and expected time of return should be discussed with the snow survey supervisor or the individual who would be in charge of a rescue operation should it become necessary. If radio contact is maintained, there is no problem of coordination, but if radio contact is not possible, a time for the rescue party to begin its operations should be determined. The state search-and-rescue units available for such an operation are recorded in the snow survey supervisor's office. This information should be accessible to the individual in charge of the rescue operation. To avoid unnecessary search-and-rescue operations, the snow survey party must inform the responsible person immediately of their return from a trip.

For trips by aircraft, a normal flight plan must be filed by the operator and a detailed description of the flight left with a supervisor or other responsible person. Flights of any kind should be attempted only under the most favorable weather conditions.

Rescue operations follow the standard operating procedure for rescue as set up in individual states under the mountain search and rescue units and state aeronautical directors. Normally the snow survey supervisor is in charge of SCS rescue or emergency operations for SCS employees.

Kinds of Travel

Foot

Skis

Skis are made of wood, plastic, or metal with a number of bindings. A plastic ski with a combination binding is widely used; this binding permits climbing and downhill and cross-country travel.

Ability to climb on skis is important to snow surveyors. Resistance to sliding can be improved by applying a climbing wax to the bottom of the skis or by using climbing skins, which are fastened to the bottom of the skis. The rough surface bites into the snow and thereby prevents sliding. Soft wax is applied in dabs along the bottom of

the skis and works in the same manner as the skins but is not as effective. After a climb is completed, the skins are removed and placed in the pack. If climbing wax is used, it must be smoothed or removed and a hard wax applied for level or downhill travel. Generally, more energy is used in climbing with skins, and more experience is needed if wax is used.

On a trip a snow surveyor should take three basic waxes--a soft or "Blue Wax" for climbing and wet snow conditions, a hard or "Red Wax" for speed on cold or powdery snow, and a wax of intermediate hardness for conditions in between. It is possible to put a harder wax over soft wax when going from climbing to downhill travel or for changing snow conditions.

Snowshoes

Snowshoes of all types are used for oversnow travel and are easier to carry on a one-man snow machine than skis. It is easier for an inexperienced traveler to use snowshoes than skis as they are more convenient for short trips and during the actual snow sampling.

There are three basic types of snowshoes:

1. The Alaskan type is normally used for snow survey trips. It has an upturn of about 12 inches on the toe and nearly parallel sides close to the center of the snowshoe. The upturn keeps the toes above the snow under soft snow conditions.
2. The Michigan type has little turnup of the toe and is widest at the middle where the foot is placed. These snowshoes are somewhat smaller and lighter than the Alaskan type. They are good for travel over hard-packed snow where the traveler's weight packs the snow less than 3 inches.
3. The Bear Paw is flat and oval in shape. These snowshoes have about 2 square feet of support area and are designed for traveling short distances or through areas of brush.

Snow surveyors should have or get some experience in using snowshoes before attempting a survey trip because snowshoes require a different gait than either walking or skiing. Unused muscles come into play, and this kind of walking, if an individual is not accustomed to it, can become extremely difficult. The same situation is true for skis except that sport skiing can prepare a skier for cross-country trips if he does some cross-country work first for training.

Footwear

Proper footwear is extremely important in oversnow travel. Ski boots should be of medium or better grade with a foam interlining. Boots ordinarily should allow space for a cotton sock and a wool sock of medium weight. Lightweight cotton or nylon socks are not adequate. Although sizes of ski boots ordinarily allow for enough sock layers as compared with regular shoe sizes, they should be checked. Shoes must be individually fitted, especially if foot travel

is extensive--a mile or more each way. Fitting should be firm but not tight to allow the toes to move freely within the boot.

Do not use shoes or boots that have hard-leather heels on snowshoes; use rubber pacs or overshoes. If only hard-heel boots are available, find some way to protect the webbing of the snowshoe. A piece of innertube tied to the hard heel or a leather or rubber patch fastened to the webbing under the heel gives adequate protection. Shoepacs should be big enough for heavy wool socks along with a pair of well-fitted cotton socks. The heavy wool cushions the tight snowshoe bindings. Since ordinary leather shoes are not watertight, they should not be used.

Ski boots should not be greased but can be waxed or treated with silicone to keep out moisture. This kind of treatment does not cause the boot to become so stiff in extreme cold. Similar treatment is used for the leather part of shoepacs.

Bindings

Ski bindings must provide for a safety release in case of a fall. A strap fastened to the ski boot prevents loss of the ski if the safety binding is tripped. Tightness of the safety binding can be increased or lessened by turning a screw or knob, depending on the make. The safety binding should be adjusted so that it can be tripped manually. The cable binding has two holders on each side of the ski; both are used in downhill skiing. The cable is removed from the rear holder for climbing and cross-country travel so that the heel can be raised from the ski surface. The cable should be tight but still easily closed with about 10 pounds of pressure on the clamping lever of the binding.

Leather snowshoe bindings that have a firm metal attachment to the snowshoe framework allow better control of the snowshoes. Two kinds of lacings are commonly used with snowshoe bindings. Nylon lacings are preferred. They are more durable than gut lacings and are not affected so much by water. They also require less adjustment during a trip. Nylon lacings need little maintenance, whereas gut lacings need to be varnished or shellacked after every trip or two.

Snowshoe bindings should be adjusted so that the ball of the foot is over the area where the binding attaches to the snowshoe. The sandal or strap section should come over the front of the foot with an inch of the shoe protruding through the binding. The rear strap should be fastened near the bottom of the heel so that the shoe sole bears most of the tension of the strap. A comfortable tightness is best.

Oversnow Machine

The predominant way of traveling to snow courses in winter is by oversnow machines. Travel is shifting from using big snow machines to small, sled-type, one-or two-passenger machines if slopes are moderate

and distances are relatively short. The big machines, such as Tucker Sno-Cat and Thiokol Trackmaster, are needed for the long hauls and difficult snow conditions. These machines have space for hauling personnel, supplies, bedrolls, and equipment and provide protection in adverse weather.

Although snow machines are not difficult to operate on hard snow on moderately sloping terrain, a considerable amount of experience and driving ability is needed for soft snow, sidehilling, and steep mountain travel. A driver must be fully trained in the operation and maintenance of the type of machine he uses.

Precautions To Take in Using Large Vehicles

1. Be sure that the machine is in good operating condition before beginning a trip.
2. Have skis or snowshoes in or on the machine for each member of the party before leaving the truck.
3. Never include a passenger who cannot at least ski or snowshoe back from a machine that is disabled at a great distance from the base truck.
4. Take along emergency rations for 2 or 3 days.
5. Carry a good snow shovel, a sharp ax, a sharp and set cross-cut saw, a first-aid kit, and a fire extinguisher. All SCS machines are required to have these items mounted in a convenient place.
6. Take enough tools and repair parts to meet the most likely breakdown emergencies; it is helpful to have someone with mechanical know-how along.
7. Understand the limitations of the machine and stay within them.
8. Hold to the road or trail and avoid shortcuts. Use caution at all creek crossings and open water. Stay off frozen lakes unless the ice has been tested.
9. Avoid avalanche areas. The rhythmic beat of a motor can cause trouble in steep sidehill country. (See avalanche section in Snow-Survey Safety Guide, Agriculture Handbook No. 137.)

Characteristics of Vehicles

Pontoon and Steel-track Type.--An example of this kind of vehicle is one of the Tucker Sno-Cats. In general, specifications for vehicles in this category (SCS-134, Specification No. OSTV-1) call for a machine that can climb a 45-percent slope on hard-packed snow, have an engine rating of at least 95 BHP, have four pontoons with steel traveling track, and hydraulic steering.

SCS uses these machines for hard, steep travel and long trips. The cab and body must be big enough for several passengers and a considerable amount of equipment and supplies. This machine must be operated on snow. If operated on mud or gravel, track wear is severe, requiring expensive repairs. A large 1-1/2- to 2-1/2-ton truck is needed for moving the machine from storage to the snow area.

<u>Fabric Belt and Cleat-type Tracks</u>.--The Thiokol Trackmaster is an example of this kind of machine. In general specifications for vehicles in this category (SCS-135, Specification No. OSTV-2) require that the machine climb a 35-percent slope on hard-packed snow, have an engine rating of at least 100 BHP, have tracks of the endless-belt type, have metal or wooden cleats and steering by selective track control. SCS uses these machines if some travel over mud and gravel is required and if slopes do not exceed the limits of the machine. There is enough space for passengers and equipment. Large 1-1/2- to 2-1/2-ton trucks are needed for moving the machine from storage to the snow area.

Specifications for machines of the belt-track type (SCS-135-Specification No. OSTV-2A) needed for special sidehilling capability require a minimum engine rating of 36 BHP and a hydraulically controlled body-leveling device for maintaining the machine body in an upright position on side-hill slopes of at least 30 percent. The Kristi Ber Kat is an example of this kind of machine. It is used where light weight and maneuverability on steep slopes are required. Space for passengers and equipment is limited.

<u>Low Power, Light-weight, Belt Track</u>.--Examples of this type of machine are the Polaris, Ski-Doo, and Ski Horse. General requirements (SCS-137, Specification No. OSTV-3 and No. OSTV-3b) are for sled-type machines having an endless belt drive and small ski for steering, 8 to 24 engine horsepower, and a payload of about 400 pounds (two people). Additional load can be towed. Pounds per square inch (PSI) range from about 0.4 to 0.75 depending on load. The driver has no protection from the weather. Although the machines can carry two persons, for most snow survey work it is preferable to have one person per machine to avoid breakdown. Greater safety is also provided since, if one machine breaks down, it can be towed out by another. There is little or no space for equipment and supplies. These machines can be used on short runs, on moderate slopes, and on well-marked trails or roads. A 1/2-ton pickup is used to haul individual machines; a pickup can haul two machines on racks, or the machines can be towed on trailers.

Use of Vehicles

It is SCS policy to permit employees to operate vehicles in emergencies that may mean loss of life. If time permits, approval of the state conservationist should be obtained first. In any event, he should be advised of the situation as soon as possible.

Any use of SCS oversnow machines by other agencies for work either related or unrelated to snow surveys must follow procedures prescribed in the SCS Administrative Services Handbook and must be approved by the responsible state conservationist. Substantially the same administrative regulations apply to carrying passengers in oversnow machines as in other SCS-owned vehicles.

Purchase

The procedure and requirements for purchasing equipment are covered in the SCS Administrative Services Handbook.

Aircraft

Use of Aircraft

Fixed-wing and rotary-wing aircraft are used extensively for observing air markers (ch. 2) and for transporting observers to make ground measurements. The advantage of using aircraft is speed in covering network stations. Personnel Memorandum - 103 (rev. 2) dated June 21, 1971, states SCS policy on the use of aircraft for making snow surveys.

Safety

Personnel Memorandum - 103 also specifies the safety limitations placed on SCS personnel and states the requirements that must be met by the pilot and contract aircraft. Each SCS employee making snow survey observations by aircraft should wear a crash helmet and a shoulder harness. It is difficult to maintain safety standards because contract operators flying in the mountains in light aircraft ordinarily do not use shoulder harnesses or crash helmets. But it is strongly recommended that they use such equipment although use is left to the individual's discretion.

Survival Needs

Regardless of whether a snow surveyor travels on skis or snowshoes, by oversnow machine, or in aircraft, he should be dressed warmly and be prepared to survive in the snow in an emergency.

Clothing

The outside garments worn by skiers or snowshoers should be made of tightly woven water-repellent material. All woolen accessories such as stockings, mitten liners and scarves should be covered by a water-repellent outer garment. Both inner and outer garments must be warm enough to protect the wearer against wind and snow and severe temperatures. Thermal or other kinds of underwear are available in a variety of weights, materials, and makes.

Most winter garments are designed so that, if the temperature rises, they can be opened and proper body temperature can be maintained without perspiration. Clothing must be kept dry. Sometimes it may be necessary to remove garments and put them in the pack.

Feet, hands, and ears are the parts of the body most sensitive to cold. Special liners, stockings, and headgear in one or more layers as required provide adequate protection. The hands, for example, should be protected by mittens with inner linings rather than by gloves, which are not suitable for remote mountain areas in cold weather. The mittens should be long enough to cover the wrists completely and to fit over the parka sleeves.

The outer parka should have a hood to protect the head, especially the ears, against the wind and to keep snow from getting into the inner garments. Sunglasses or goggles are an absolute necessity for protecting the eyes against the glare of the sun and the force of individual crystals of snow accompanied by high winds.

Food

To Carry on Trips

The food taken on a snow survey trip should be dehydrated and high in protein and carbohydrates. If trips are 2 or more days long, canned or fresh food should not be carried. A minimum amount of equipment for reconstituting dried or processed food is usually a pot with a handle in which to melt snow. Examples of dehydrated food are beef, fruit, milk, coffee, chocolate, bouillon, and fruit juice. Chocolate bars are excellent emergency rations. All these foods are in grocery stores. Special survival food lists at sporting-goods stores contain all or part of these items. "In flight" dehydrated ration lists are available from the General Services Administration, Federal Supply Schedule, Group 89, Part 3. Canned rations used by the U.S. Army or by certain civilian groups are not too suitable for foot travel because of their bulk and weight but are suitable for use in oversnow machines, in cabins, or on air flights. Except in emergencies special rations for SCS snow surveyors should be requisitioned from the SCS state office.

In Shelter Cabins

For foot trips on which an overnight stay is planned, cabins are usually available. They are stocked with food before the snow season begins. Unless frostproof storage is available, emphasis should be on dehydrated rather than canned food. Freezing does not make canned food unfit for use as long as it stays frozen, but flavor does deteriorate. Thawed canned food should not be used, which makes it necessary to replace food in cabins each season.

The cache of food in these isolated cabins must be protected not only from rodents but also from freezing and theft. One method of food protection is to build a concrete pit, which has the bottom and sides lined with Celotex, beneath the floor of the cabin. This insulating board is nailed to pieces of plank, 1 inch by 4 inches, arranged to leave an airspace between the board and walls and floor. A heavy trap door in the floor with covered hinges and a padlock covers the pit. After the provisions in bags are lowered into the pit, a loose metal cover is placed in a recessed section at the top of the concrete walls and on top of this a layer of Celotex and bags of dry pine needles to fill the space tight against the under side of the trap door. In stocking the cabin with food supplies something substantial should be left in the cabin within easy reach in the event of an emergency.

Another way to preserve food is in a locked box made of reinforced concrete placed in one corner of the cabin. This box should have inside length, width, and height dimensions of 40, 26, and 18 inches respectively.

Shelter

Emergency Shelters

Ordinarily, snow survey trips are not scheduled if it seems likely that surveyors may have to sleep outside in the snow. But accident, extreme weather, or becoming lost may make it necessary. Snow surveyors should expect that they may have to stay in the snow whenever a trip is made by air or if a round trip on foot takes more than 4 hours under adverse travel conditions. A snow surveyor should learn how to build an emergency shelter and know what to do before he is in an emergency situation. Any arrangement that provides shelter from wind and snowfall and a place to lie down is satisfactory.

Snow surveyors should read and practice instructions in the SCS pamphlet "Survival in Snow." Briefly, it describes how to build snow shelters. Some possibilities include building a shelter under a tree where the snow is not as deep as elsewhere, a shed made of limbs and boughs on top of the snow, a trench in the snow in open areas, and a snow cave dug into snowbanks. After the snow is packed, the snow surface is covered with boughs to provide insulation; boughs supported by small pole branches can be used to make a roof over the trench or bough shelters. Snow temperatures of 25° to 30° F. are much higher than nighttime air temperatures in the mountains, and these snow shelters provide substantial protection from wind. For added warmth, a fire can be built if a layer of green boughs is first placed on the packed snow. Figures 4-1, 4-2, 4-3, and 4-4 show different kinds of shelters.

Shelter Cabins

With remote snow measuring devices, air markers, and better and faster oversnow machines, the use of cabins is becoming less frequent. But where men require overnight lodging or may be forced to remain overnight due to mechanical failure of their snowmachines, shelters must be provided.

Shelters are generally located on national forest land; a "special-use permit" must be obtained from the forest officer in charge. Issuance of the permit depends on selection of a suitable location, provision for adequate sanitary facilties by the applicant, and shelter construction of an approved type.

Location Criteria.--In locating a shelter cabin the following points in order of importance should be considered:

1. Distance from snow courses or to other shelter facilities.
2. Freedom from danger of falling trees or snow or dirt slides (snags or ripe trees in such positions as to damage the shelter if blown down should be felled before starting construction).
3. Accessibility for moving materials to the site (some of the shelter cabins have been built with logs, and wood is used for fuel)
4. Seclusion (it is desirable that the cabin be shielded from view of trails or roads to minimize trespassing).

ORE-75284

Figure 4-1.--Tree shelter.

CO-7476-10

Figure 4-2.--Bough shelter,

IDA-45343

Figure 4-3.--Snow cave shelter.

IDA-45342

Figure 4-4.--Trench shelter.

5. Drainage (the site should be leveled and ditched to drain the surface runoff completely away from the shelter).
6. Availability of water supply.
7. Minimum danger from fire (the site should be adequately cleared for such a distance as to reduce the danger of spreading fire to the woods should the cabin burn or to prevent destruction of the shelter by any ground fire in the forest).

Types.--Several types of structures are used in the snow survey program. These types vary widely from the primitive log cabin to the modern fiberglass prefabricated cabin. Even much smaller shelters made from a section of culvert pipe are in use. The latter, however, are built to house radio equipment and only provide shelter in extreme emergency. Most of the cabins are of the primitive type and are generally of two designs, the Colorado type (figs. 4-5 and 4-6) and the Oregon type (deep snow) with Santa Claus chimney (figs. 4-7 and 4-8).

Colorado.--The Colorado type is used where total snow depth seldom exceeds 6 to 8 feet. A plan has been adopted that provides a framed structure with log cabin siding, Celotex lining, floor and with the entrance door that is only slightly above ground level protected by an overhanging porch. It has an emergency gable entrance.

This type as well as the Oregon type (deep snow) should include the following comfort and safety features: comfortable bunks; bedding in rodent-proof storage; stove placed on a large sheet of galvanized iron to prevent fire; chimney of brick or rock resting on a concrete footing; and heavy storm shutters covering the windows to help prevent intrusion

BN-38792

Figure 4-5.--Colorado-type shelter cabin.

during off-season. The cabin also should have a large wooden box, a rodent-proof insulated food cache including dishes, a table, and chairs. A list of materials for building the Colorado-type cabin follows:

26 sacks of Portland cement, 2.75 cubic yards of sand, and 4.5 cubic yards of gravel for concrete (1:3:5 mix for foundation and piers, and 1:2-1/2:4 mix for storage pit)

450 common hard burned brick for chimney

2 sacks of Portland cement, 1 bushel of lime, and 1/4 cubic yard of sand for mortar for chimney

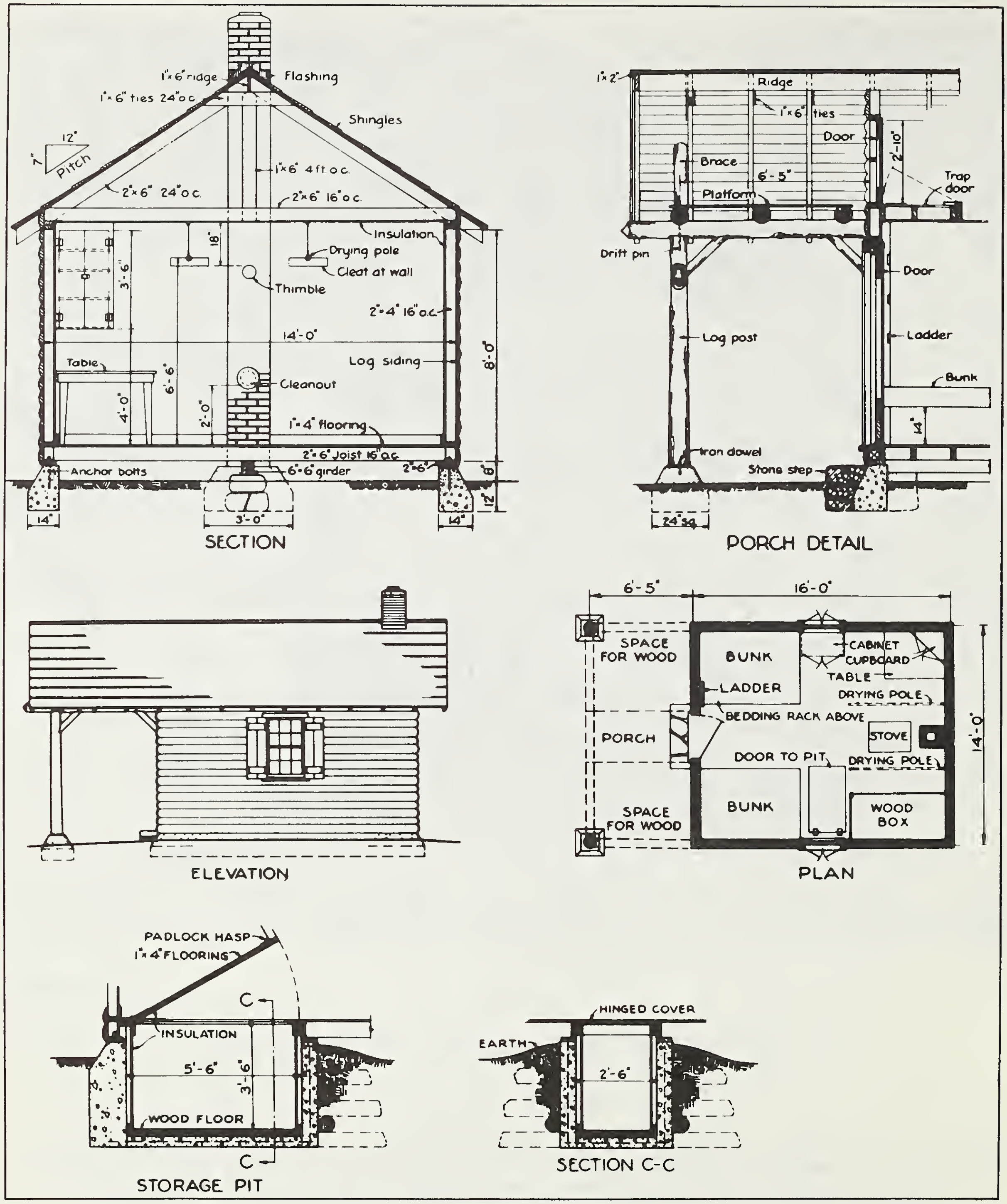

Figure 4-6.--Plan, elevation, and section of Colorado-type shelter cabin.

12 linear feet 8 inches by 8 inches terra-cotta flue lining

6 pieces 2 inches by 6 inches by 16 feet for sills and headers

28 pieces 2 inches by 6 inches by 14 feet for sills and joist headers

32 pieces 2 inches by 6 inches by 10 feet for rafters

1 piece 6 inches by 14 feet for girder

34 pieces 2 inches by 4 inches by 16 feet for plates, sills, studs, and blocking

20 pieces 2 inches by 4 inches by 14 feet for plates, sills, studs, and headers

4 pieces 2 inches by 4 inches by 16 feet for strips for storage pit

7 pieces 1 inch by 6 inches by 16 feet for ties and corner brace battens

144 linear feet 1 inch by 4 inches for baseboard and roof-ridge

24 linear feet 1 inch by 8 inches for ridge

650 board feet of 1 inch by 8 inches shiplap for roof-sheathing

325 board feet 1 inch by 4 inches tongue and groove fir for flooring

672 square feet Celotex for insulation

750 board feet 2 inches by 6 inches log cabin siding

2 rolls of waterproof paper (500 square feet per roll)

Shingles to cover 520 square feet of roof

1 five-panel fir door 2 feet 8 inches by 6 feet 8 inches with frame and trim

2 windows, double hung plain rail, 12 lights 8 inches by 10 inches with frame and trim

NOTE: Hardware, paint, stone, logs, poles, and furnishings are not included.

Oregon.--Where snow depths normally cover a one-story structure completely, the Oregon-type (deep snow) cabin is better suited. Figure 4-8 shows plan, elevation, and section views outlining the most important features of the construction. Details are not given since most builders use their own methods. The two most distinctive features of this type of

ORE-75,360

Figure 4-7.--Oregon-type (deep snow) shelter cabin with Santa Claus chimney.

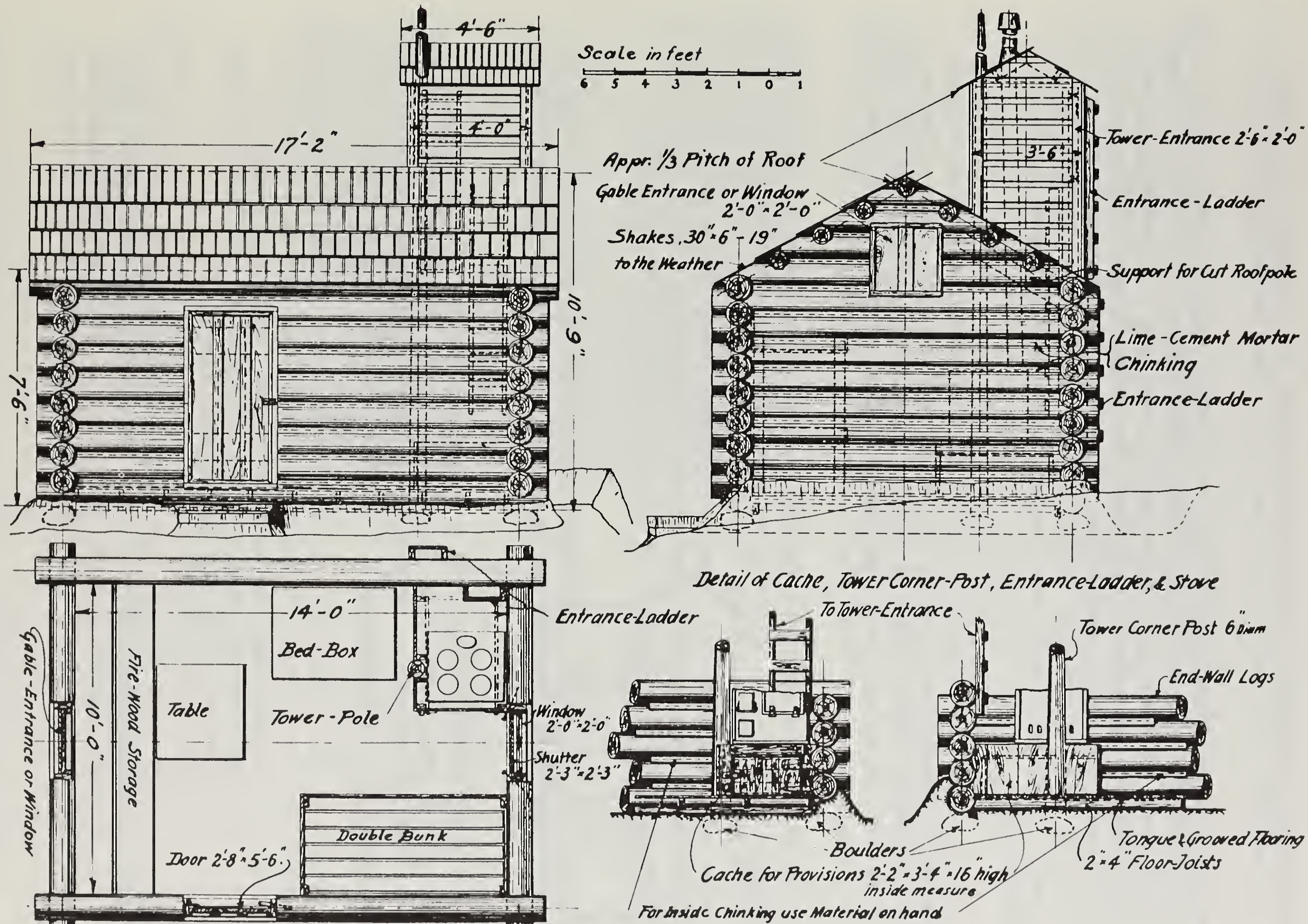

Figure 4-8.--Plan, elevation, and section of Oregon-type (deep snow) shelter cabin, including Santa Claus chimney.

shelter, however, are the tower entrance that is designed to extend above the maximum snow depths and the solid construction of the cabin.

If the tower is exceptionally tall, two entry doors should be built, one at the top and the other about 10 feet above ground. For a short tower, the inside corner pole plus cross-bracing provides such strength that the tower need not be guyed to prevent its being blown off the cabin. Very tall towers probably need to be guyed to the cabin corners or nearby trees. Guys of unequal length should be avoided. Ladders both inside and outside the tower are needed to enter the cabin through tower doors.

The stovepipe should run up the inside of the tower, with two or more baling wire cross-braces to make it rigid, and it must have a damper. Any sort of cover can be used. A large tin can attached to a pole that can be reached from the tower door is suitable, for this cover may then be easily removed or replaced when entering or leaving the cabin.

Prefabricated.--These shelters usually have a fiberglass sandwich-type construction (fig. 4-9). If the structure can be placed in an area where electricity is available, using electric heat and ventilation makes this cabin extremely satisfactory. These buildings need little maintenance and can be placed easily on above-ground foundations. These units can be made comfortable by installing hot-plate cooking units and modern chemical toilets.

The shelters for telemetry equipment can be used as emergency shelters if they are made large enough to house both the radio equipment and two men.

The Nevada snow survey group uses a 16-gauge, 72- by 44-inch aluminum pipe arch cut 8 feet long. This pipe arch can be closed at one end and a door affixed to the other. By stocking it with rations, candles, and sleeping bags, this unit doubles as a survival shelter in emergencies.

Orientation.--If the front door of the Oregon-type shelter faces the prevailing wind, tower entrance doors are then in the lee of the wind and not so likely to permit snow to blow in around door cracks that are exposed to drifting snow all winter. The entrance of the Colorado-type shelter should face away from the prevailing wind.

Dimensions.--Shelter dimensions may vary, depending on expected use and on the size of snow survey parties. For the usual two-man party, 10 by 14 feet is adequate; 12 by 14 feet and 12 by 16 feet are adequate for three- and four-man parties respectively. There also should be enough headroom.

Storage.--Bedding and supplies stored in the cabins should be protected from rodents. A lightweight rack may be suspended by cables of rope or wire at each corner, these cables passing over pulleys hung from the rafters, thus anchoring the mattress, blankets, tarpaulin, and supplies

in a hard press against the ceiling. In this way rats and mice cannot reach the bedding.

Most of the cabins should be stocked with food, fuel, bedding, and a lantern in late fall, before the permanent snowpack, to avoid vandalism as much as possible. A supply of wood sufficient for three or four winters can be stored against the back wall of the primitive-type cabins. The prefabricated-type cabin can be supplied with canned heat or a small gas camp stove.

It is important to stock a shelter thoroughly so that the snow surveyors can obtain warmth, food, and rest without delay.

All survival cabins used by SCS must be locked to discourage entrance by vandals or the public. They also should be posted with the SCS snow survey shelter signs (fig. 4-10) designed for such cabins.

Figure 4-9.--Prefabricated shelter cabin. Note power supply line that furnishes electric heat and ventilation.

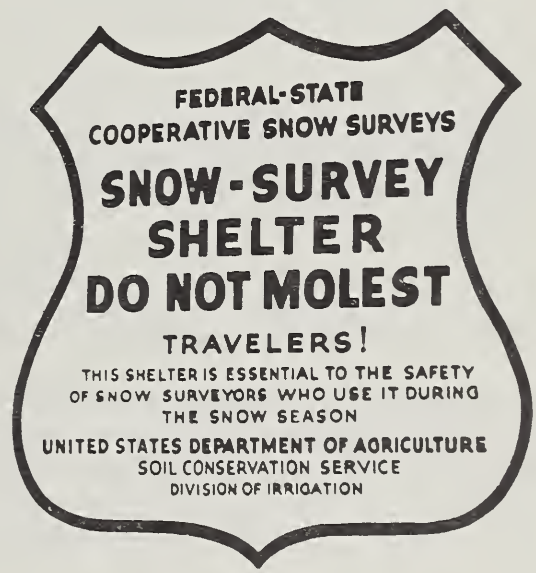

Figure 4-10.--Shelter cabin sign, constructed of 1/4-inch or 3/8-inch Masonite or hardboard.

Equipment

For survival in the snow a supply of matches in a waterproof container is essential. A light sleeping bag and a hand ax also will help insure survival for some time without undue hardship. If staying out in the snow for a long time is a possibility, snow surveyors should carry the following equipment:

1. Sunglasses
2. Knife
3. Compass
4. Maps
5. Signal equipment--flares or panels if possible
6. Small first-aid packet
7. Tarp or plastic sheet
8. Stub candle
9. High-protein, high-calorie dehydrated rations
10. Light cooking gear
11. Light rope or nylon line
12. Container with handle or pail to melt or hold water
13. Hatchet

An aircraft, in the event of a crash landing, should carry a small sleeping bag, hatchet, matches, fire starter, first-aid kit, some food, bearpaw snowshoes, and possibly other survival equipment.

Health and Safety

Physical Condition of Snow Surveyors

Persons must be physically able to make specific snow survey trips without undue exertion. Physical examinations are required of all SCS employees making snow surveys each year. A person who is not accustomed to outdoor work or strenuous activity should take short trips or exercise to get in shape for extended trips (see SCS Personnel Memorandum No. 6).

Preparation for a trip and the physical fitness of the snow survey party should be such that the party can return by foot from the most remote location. The pace of the trip must be set within the limits of the least fit individual. Further, attempts to exhibit competitive physical stamina or skill in skiing have no place on such a trip. Persons with physical defects should not be in snow survey parties even if the trip is made by oversnow machine or aircraft. Sickness, injuries, or accidents may require a special plan of action.

Hazards of Trip

Winter safety depends on the skill of the individual, and, due in large part to SCS's training program, the safety record of the snow surveyors has been excellent. Adverse weather, avalanches, and accidents are not

major hazards when snow surveyors understand the hazards and are prepared to cope with them. A person who panics limits his chances of survival, but safety training and experience reduce the possibility of mishaps. Snow surveyors should not drive themselves to physical exhaustion except in an extreme emergency. Plenty of time should be allowed for trips as accidents and physical discomfort are more likely to occur when people are hurrying or are tired. All movements should be steady and deliberate; the impulse to get the job done quickly and return home to warmth must be controlled. Snow surveyors must anticipate possible trouble, have a plan, and practice self-control under emergency conditions.

Snow-Survey Safety Guide, Agriculture Handbook No. 137, contains many tips for safe winter travel in remote areas as well as for emergency first aid. Each snow surveyor should have a copy in his pack and in his sampling set, and a copy should be placed in every oversnow machine and aircraft used for snow surveys.

Some of the hazards to be prepared for on such a trip follow.

Becoming Lost

If a snow survey party traveling on foot becomes lost, usually because of lack of visibility, it should stay together and backtrack until the surroundings are recognized. Absolute control by a predesignated party leader is essential. If the party is definitely lost or visibility is limited by weather or approaching darkness, it should bivouac immediately. With a minimum of equipment the party can survive in reasonable comfort until it can proceed safely to a known destination or a rescue party arrives. A fire that produces smoke helps the rescue party locate the snow surveyors.

If travel is by machine and a breakdown occurs or the party becomes lost, no one should leave the machine until rescue attempts can be made or the party is sure they can reach safety. Travel should be attempted only in daylight and in good weather. The machine provides shelter and can be spotted easily from the air. Travel should be downhill to maintain direction and provide the best opportunity to reach roads, shelter, and a more favorable climate with a minimum of fatigue. Standardized ground-to-air emergency signals are also in the Snow-Survey Safety Guide.

Avalanches

Routes to snow courses should be as far as possible from areas where there is danger of avalanche such as those at the bottom of or on steep slopes in the mountains. Avalanche areas can be recognized from paths down the slope where previous avalanches have run and tree cover has been swept away. Avalanches are most likely to occur during or soon after heavy snowfall, 12 inches or more. New snow falling on a relatively dense, consolidated snowpack adds to the danger as does steepness of slope. Slopes of less then 35° usually do not have major avalanches. The following precautions will reduce danger from avalanches:

1. If danger is involved, the area should be avoided.

2. On foot trips, one individual at a time should cross the avalanche area.
3. In oversnow machines, the driver with the vehicle should cross the area first with others in the party following after the driver and machine are safely across.
4. Automobiles or trucks should not be stopped or parked on the highway in avalanche paths.

If a member of the snow survey party is caught in the path of an avalanche, he should try to outrun it. If he cannot, he should make every effort to stay on top of the snow while the avalanche is still running. If he is buried when the avalanche stops, he should try to make an air space around his face. Most avalanche deaths are caused by suffocation.

Other members of the party should note carefully the place where the victim was last seen. Immediate rescue procedures should be started, searching first for surface evidence. If there is no visual evidence (gloves, cap, ski pole, and the like) of the location of the person, long slender sticks should be used to probe across the fall line below the point of disappearance. Probing should be done on about a 6-foot grid or less depending on the size of the rescue party. Speed is essential since suffocation and shock are the greatest dangers (see Snow Avalanches, Agriculture Handbook No. 194).

Accidents

Snow survey employees should know how to apply first aid. Some first-aid training is usually given to them at the snow survey training schools. Surveyors should be thoroughly familiar with the Snow-Survey Safety Guide, Agriculture Handbook No. 137, and the First Aid Guide for USDA Employees, Agriculture Handbook No. 227.

Frostbite, shock, and injury are the most common conditions requiring first aid. Treatment for these conditions follows:

> Frostbite. Note presence by gray color of skin. Treat by cover, warmth, and shelter.
> Shock. Treat with warmth and provide shelter and assurance of safety and rescue. Avoid leaving a person in shock alone.
> Injury. Place the person in as comfortable a position as possible and provide warmth. Expect shock. Stop any excessive bleeding.

If possible, obtain help. A minimum of moving the injured with emergency or makeshift equipment should be attempted. If emergency transportation over snow is necessary, a snow sled made from the injured person's skis, ski climbers, shoe laces, pieces of wood, ski poles, and miscellaneous equipment is the most readily available means of transport (see p. 29 of the Snow-Survey Safety Guide).

CHAPTER 5. DATA PROCESSING

CONTENTS

Figure

Table

Chapter 5. DATA PROCESSING

The effectiveness of the SCS water supply forecasting activity is determined to a large extent by the quality and character of the data processing procedures and techniques. Maps, records, and data summaries must be kept up to date in a format suitable for rapid access and evaluation.

The discussion and description of data processing methods that follow should not be construed as inclusive. Each reader should choose the methods best suited to his needs or adapt the methods given.

Maps of Field Installations

Maps of the various field installations are required for efficient operation of the forecasting activity. These maps include the location of snow courses, aerial markers, soil moisture stacks, pressure pillows, precipitation gages, and other special field installations.

Enough copies of 8- by 10-1/2-inch and 4- by 5-inch map prints should be ordered to supply all offices and field personnel concerned. The 4- by 5-inch prints are favored by field men because they conveniently fit in the sampling-set notebook. Figure 2-2 is an example of a typical snow course map. The same general format is recommended for other installations.

Distribution procedures vary in the West, but the following distribution pattern is a general guide:

	Sets of pertinent maps (one large, one small)
State office (snow survey supervisor)............	Originals and 5 to 10 extra
Area office (optional)...........................	1
Work unit (optional).............................	1
Field man..	2

The master map file is kept in the snow survey supervisor's office. Maps can be filed in labeled folders in alphabetical sequence or according to the grid system for numbering snow courses.

In this grid system, which is used to designate snow courses, aerial markers, soil moisture stacks, and precipitation gages, the numbers assigned are based on coordinates of 1° of latitude and 1° of longitude to form cells within which snow courses are numbered from 1 to 99. Each cell is designated by a number and a letter.

For example, figure 2-2, Morse Lake Snow Course (21C17), is located in the cell that is bounded by 121° and 122° longitude and 46° and 47° latitude. Number 21 designates longitude and the letter C designates latitude.

Numbers designating longitude are derived by subtracting 100° from the lesser of the two longitude values. Letters designating latitude start in the first cell tier south of the Canadian border and run south as A, B, C,...Z; I, O, and Q are omitted. Number 17 following 21C differentiates Morse Lake from other snow courses in the cell. A soil moisture station at or near the snow course is indicated by the letter M. An aerial marker at the snow course is indicated by the letter A. A precipitation gage is indicated by the letter P.

All maps should be kept current. If a major change occurs, a new master map and copy prints should be prepared. At least one copy of each outdated map should be kept in the file folder for reference. A biography form should be filled out for each snow course, soil moisture station, aerial marker, or other installation. These forms should be filed for reference and kept current (see figs. 2-3 and 2-24).

Records

Data Collected by SCS

Snow Survey

At the present time, SCS uses snow sampling equipment, aerial markers, and pressure pillows to measure snow depth and water equivalent.

Procedures for Computing and Recording Snow Survey Notes.--SCS has standardized procedures for computing, checking, and recording standard snow survey notes from the field as follows:

Step 1. Check heading of snow survey note for completeness.

Step 2. Subtract each value in column 5 from column 6 to get Water Content Inches (column 7).

Step 3. Divide each value in column 7 by Depth of Snow Inches in column 3 to get Density Percent (column 8).

Step 4. Add columns 3, 5, 6, and 7 separately. Subtract total of column 5 from total of column 6 to check total of column 7.

Step 5. Divide column 3 and column 7 by the number of sampling points to obtain the averages. Round off the average snow depth to the nearest inch and the average water content to the nearest 0.1 inch.

Step 6. Divide column 7 rounded average by column 3 rounded average to get the average density for column 8. Round off average density to the nearest full percentage value.

Step 7. Check back of notes for sampling conditions. Remarks on average conditions appear in column 9.

Step 8. If one or more of the individual measurements of water content seem to be in error because of poor sampling, ponded water, and the like, calculate the estimated water content as follows:

A. Add the snow depth for all sampling points at which satisfactory values of water content were obtained (as deduced by comparable density values).

B. Add the satisfactory values of water content for the same group.
C. Divide B by A to get the average density of the snow cover of the group of satisfactory measurements.
D. At the sampling points for which the index of water equivalent seems in error, multiply snow depth by C to get the calculated water content.
E. Then compute the full set of notes by procedures 2 to 6.

Step 9. Have one person compute each set of snow notes and another check for arithmetical accuracy of the first order. Enter the initials of each person computing or checking the snow notes at the bottom of the notes (see fig. 5-1 for steps 1 through 9).

The following steps are optional:

Step 10. Record the averages from the snow note form on the permanent file form "Record of Snow Course Measurements" (see fig. 5-2).

Step 11. Record the average water equivalent on "Record of Water Equivalent" form. This form is filed alphabetically or in some other meaningful system.

Step 12. At the end of each snow season bring the "Record of Water Equivalent" form up to date as follows:

A. Add the past season's water content to the previous totals of water content.
B. Add 1 year to the previous number-of-years totals.
C. Divide the new totals of water content by the new number-of-years total to get the new average water equivalent.
D. If appropriate, recompute 15-year averages.

(See fig. 5-3 for steps 11 and 12.)

Aerial marker readings are reported on form SCS-166 (see fig. 2-11 for computation).

Pressure pillow readings are converted into inches of water by using appropriate conversion factors and tables. The charts or recordings should be transcribed on suitable summary forms (see ch. 2). Records of results and interpretations should be filed permanently by snow course and by year in a fireproof place.

Microfilming Original Snow Survey Notes.--All snow notes and aerial marker notes should be microfilmed. After the first microfilming has been completed, new notes should be microfilmed at least every 5 years. Two copies (one positive and one negative) should be prepared. The negative should be sent to the Records and Communications Management Branch, Administrative Services Division, Soil Conservation Service, Washington, D.C. 20250, and the positive retained in the state office.

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SCS-708
(8-58)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FEDERAL AND STATE
COOPERATIVE SNOW SURVEYS

State Oregon

Drainage Basin Row River

Snow Course Champion

Party Kenyon - Foster

Date 4-1-69

*Description or Number of Course (1)	†Sample Number (2)	Depth of Snow Inches (3)	Length of Core Inches (4)	Weight of Empty Tube (5)	Weight of Tube and Core (6)	Water Content Inches (7)	Density Per-cent (8)	Remarks (See reverse) (9)
#22F9	1	91	89	62	103	41	45	
	2	97	93.5		104	42	43	
	3	90	88		104	42	47	
	4	90	88		101	39	43	
	5	92.5	89		102	40	43	
	6	93.5	91	62	105	43	47	
	7	91.5	89		105	43	47	
	8	92	88.5		105	43	47	
	9	90	89		101	39	43	
	10	96	86.5	62	101	39	41	GNF
Total (10)		923.5		620	1031	411		
Average		92.4				41.1		
		92					45%	

*Show number or description as given on sketch map, *i. e.*, "Course No. 1," or "Major Course," or "N 5° E," etc.

†Always start measurements for sampling from the *initial* point as shown by the sketch map of the course and follow the spacing for samples as indicated. Particular care should be taken to note any *irregular* spacing between samples.

No. 1 of 1 sheets. Comp. by Kenyon Checked by T.A.G.

NOTE.—Please fill in while in the field.

DATE OF SURVEY: Began 8:20 a.m. ~~p.m.~~ Ended 8:45 a.m. ~~p.m.~~

SAMPLING CONDITIONS

(Please check items descriptive of present conditions.)

Weather at Time of Sampling

✓ Clear, ... Partly cloudy, ... Overcast, ... Raining,
.... Snowing, ... Blowing, ... Freezing, ✓ Thawing.

Snow Conditions at Snow Course

Snow samples obtained with ✓ ease, ... moderate difficulty.*
Snow samples obtained with .... extreme difficulty.*
Ground under snow: .... frozen, ... not frozen, ... dry, ... damp, ✓ wet (saturated).
Ice layer on ground No How thick? .... inches.

General Snow Conditions

1. What elevation is snow line generally? 3000 ft.
2. Is snow melting on north and east slopes? Yes
3. Is snow melting on south and west slopes? Yes
4. How many inches of new snow at snow course? 0 in.
5. Is there evidence of snowslides? No

General Stream-Flow Conditions

1. Are very small streams running? Yes ✓ No ....
2. Are small streams bridged over by snow? Yes .... No ✓
3. Are streams clear or muddy? (*Check one*) Clear ✓ Muddy ....

*Explain fully under remarks.

PRECIPITATION DATA

Month	Day	Year	Precipitation	Readings		Dipstick	Weight
			Current		Made by (check)		
			Previous				
Station name			Catch, inches		Scale number		
			After recharge				

REMARKS:

U.S. GOVERNMENT PRINTING OFFICE : 1962 O—645907

Figure 5-1.--Field note form (office checked).

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
OREGON

No. 22F9
Elev. 4500'
Card No. 6

CHAMPION (Revised Data)
(Snow Course)

Basin 12

RECORD OF SNOW COURSE MEASUREMENTS

YEAR	MONTH	DATE	SNOW	WATER	DENSITY	REMARKS
1966	Mar.	3/1	108	38.8	36	GNF-damp
	Mar.	3/15	102	43.0	42	GNF
	Apr.	3/31	102	49.2	48	Ground damp
	Apr.	4/15	80	42.8	54	GNF-damp
	May	4/29	61	28.7	47	Ground damp
1967	Jan.	1/3	28	9.5	34	GNF-wet
	Jan.	1/16	35	12.6	36	GNF-damp
	Feb.	1/31	53	18.8	35	GNF-wet
	Feb.	2/16	66	20.7	31	GNF
	Mar.	3/2	68	23.8	35	GNF-damp
	Mar.	3/16	73	28.8	39	GNF-damp
	Apr.	3/31	88	31.8	36	Ground damp
	Apr.	4/14	84	31.3	37	GNF-damp
	May	4/28	93	39.1	42	GNF-damp
1968	Jan.	1/2	41	12.8	31	GNF-damp
	Jan.	1/15	49	17.1	35	GF-damp
	Feb.	1/31	70	19.4	28	GF-damp
	Feb.	2/15	53	21.1	40	GNF-damp
	Mar.	2/29	18	8.2	46	Ground wet
	Mar.	3/15	30	11.5	38	GNF-damp
	Apr.	4/1	24	11.9	49	GNF-damp
	Apr.	4/15	22	9.9	45	GNF-damp
	May	4/30	4	1.2	30	Ground damp
1969	Jan.	1/2	56	17.1	31	Ground wet
	Jan.	1/15	86	23.7	28	GF-dry
	Feb.	2/14	111	39.0	35	GF-damp
	Mar.	2/27	107	40.2	38	GNF-damp
	Mar.	3/14	117	45.4	39	GNF-damp
	Apr.	4/1	92	41.1	45	GNF
	Apr.	4/15	89	41.5	47	GNF-damp
	May	4/30	77	37.7	49	Ground damp

GNF – Ground not frozen
GF – Ground frozen
T – Trace

a – telephone
b – partly estimated – see notes

USDA-SCS-PORTLAND, OREG. 1960

Figure 5-2.--Permanent file form for record of snow course measurements.

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
OREGON

CHAMPION (Revised Data)
(Snow Course)

No. 22F9
Elev. 4500'
Card No. 2

RECORD OF WATER EQUIVALENT

(from surveys made on or about....)

SEASON	JAN. 1	JAN. 15	FEB. 1	FEB 15	MAR. 1	MAR. 15	APR. 1	APR. 15	MAY 1	MAY 15	JUNE 1
1956-57	0.6	4.7	9.2	12.0	10.3	12.8	16.9	10.9			
1957-58	12.6	19.4	21.4	24.2	21.5	28.7	27.9	27.3			
1958-59	0.0	0.7	0.5	6.2	12.9	11.9	17.4	11.5			
1959-60	3.9	8.2	11.5	16.9	23.7	31.9	28.9	22.2			
1960-61	3.3	2.6	0.0	3.6	8.4	18.4	24.8	19.5			
1961-62	12.4	11.0	14.4	14.6	17.8	28.8	31.2	21.6	17.0		
1962-63	0.0	0.2	2.4	0.0	0.0	1.0	9.7	10.5	14.3		
1963-64	0.0	10.6	23.5	26.4	28.5	40.1	40.9	43.5	36.6		
1964-65	--	19.6	23.6	--	28.7	--	23.2	--	9.7		
1965-66	14.7	29.0	30.7	35.2	38.8	43.0	49.2	42.8	28.7		
1966-67	9.5	12.6	18.8	20.7	23.8	28.8	31.8	31.3	39.1		
1967-68	12.8	17.1	19.4	21.1	8.2	11.5	11.9	9.9	1.2		
1968-69	17.1	23.7		39.0	40.2	45.4	41.1	41.5	37.7		
Total	173.9	285.3	504.4	434.6	692.7	420.3	902.4	375.0	203.3		
Years	(20)	(20)	(30)	(20)	(31)	(15)	(31)	(14)	(9)	( )	( )
Average	8.7	14.3	16.8	21.7	22.3	28.0	29.1	26.8	22.6		
15 Yr. Average	7.7^h	13.3^m	16.4	20.9^m	21.9	27.8^m	30.2	24.4^m	26.3^h		

USDA SCS PORTLAND OREG 1960 M-2944

h- Adjusted Average
m- Average for 5 or more years in 15-year period

7-L-15000-349

Figure 5-3.--Permanent file form for record of water equivalent.

Soil Moisture
Soil moisture readings should be arranged in an alphabetic, grid, or other logical filing sequence. Summary data can be listed on forms similar in format to figures 5-2 and 5-3.

Data from Other Agencies

For water supply forecasting purposes, data obtained by other federal, state, and private agencies also are needed. Some of these data are:

1. Measurements of lake levels and flows of streams and deep-seated springs and observations of ground-water fluctuations.
2. Measurements of precipitation, air temperature, surface wind movement, and similar physical environmental or meteorological observations.

U.S. Geological Survey
Streamflow.--Streamflow measurements are recorded in "Surface Water Supply of the United States," which is part of the Water-Supply Papers published yearly by the U.S. Department of Interior's U.S. Geological Survey. Each part contains the records for an area whose boundaries coincide with natural drainage basins. Each snow survey supervisor should have a full set of these papers for his area of interest.

Figure 5-4 shows how streamflow volume data can be retabulated. The data are shown on a water-year basis. All the streamflow data for a particular station on a stream are collected; summations are shown for the important seasonal periods, and the averages are shown for each month or group of months for the period of record. Tables showing maximum and minimum mean daily flows and date of each for each month for all the years of record also can be prepared as shown in figure 5-4.

Reservoir Storage.--The Surface Water Supply Papers are the principal source of published reservoir storage data. Provisional information is obtained for the most part directly from the agency or group managing the reservoir or from a state agency.

Figure 5-5 shows a form used for recording these data. Averages for the various months or periods can be readily obtained from this form. Additional columns can be added to this form if necessary to show reservoir losses or gains for the important seasonal periods.

Base flow.--The Geological Survey provides, on request, base flow data (ground-water inflow into a river) such as shown in table 5-1.

STREAM: JORDAN CREEK above LONE TREE CREEK, near JORDAN VALLEY, OREGON

Location: Lat. 42°53', long. 116°59', in NW$\frac{1}{4}$ sec. 19, T. 6 S., R. 5 W., on left bank 2 miles upstream from Lone Tree Creek and 7 miles southeast of Jordan Valley.

Drainage area: 450 sq. mi., approximately.

RECORDS AVAILABLE: October 1945 to January 1953, April 1955 to September 1960. October 1945 to January 1953 at site 2 mi. downstream, records equivalent except during late summer months when considerable difference may result from irrigation and return flow between sites.

Remarks: Diversions above station for irrigation.

RUNOFF IN ACRE-FEET

Yrs. of Record	Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	May-July	Apr.-July	Apr.-Sept.
1	1945-46	728	1,910	4,420	6,560	5,560	30,200	78,350	35,090	8,400	1,430	363	392	44,920	123,270	124,025
2	1946-47	958	1,710	2,710	1,950	6,750	14,580	25,680	13,020	4,060	640	162	174	17,720	43,400	43,736
3	1947-48	523	1,240	1,780	4,680	3,570	5,750	32,650	33,420	9,940	1,500	338	257	44,860	77,510	78,105
4	1948-49	441	819	976	1,110	1,380	10,740	47,460	25,570	5,380	608	127	120	31,558	79,018	79,265
5	1949-50	548	825	855	3,110	6,490	18,880	44,440	32,970	12,040	1,590	383	279	46,600	91,040	91,702
6	1950-51	676	2,390	9,510	8,850	35,460	23,950	72,380	35,200	7,680	1,220	335	255	44,100	116,480	117,070
7	1951-52	865	1,580	3,030	2,730	6,090	13,860	124,800	94,330	22,760	4,590	761	355	121,680	246,480	247,596
8	1952-53	644	1,140	1,500	7,110	-	-	-	-	-	-	-	-			
	1953-54	-	-	-	-	-	-	-	-	-	-	-	-			
9	1954-55	-	-	-	-	-	-	21,910	46,350	11,510	1,650	208	127	59,510	81,420	81,755
10	1955-56	241	1,020	10,720	17,660	7,750	38,870	63,080	44,790	10,690	1,320	329	181	56,800	119,880	120,390
11	1956-57	994	2,160	4,980	1,900	21,380	33,710	44,260	60,140	13,340	1,490	284	221	74,970	119,230	119,735
12	1957-58	752	1,320	1,860	2,270	16,960	11,820	49,140	62,870	13,230	1,690	481	178	77,790	126,930	127,589
13	1958-59	381	1,050	1,740	2,500	2,630	5,780	19,890	11,290	3,680	431	101	396	15,401	35,291	35,788
14	1959-60	2,020	1,170	936	1,210	4,500	32,120	36,420	18,170	4,980	407	128	105	23,557	59,977	60,210
15	1960-61	167	897	1,070	1,150	4,390	12,570	24,080	14,640	3,970	340	71	127	18,950	43,030	43,228
16	1961-62	312	833	1,020	2,260	7,410	10,620	42,690	22,110	7,010	636	110	71	29,756	72,446	72,627
17	1962-63	339	937	1,520	2,150	16,670	7,050	16,400	21,730	11,320	1,530	206	107	34,580	50,980	51,293
18	1963-64	322	2,040	1,670	1,680	1,920	12,360	56,740	42,830	18,790	2,100	295	263	63,720	120,460	121,018
19	1964-65	594	1,430	45,070	35,250	33,260	17,550	58,320	45,050	17,640	2,520	1,060	1,160	65,210	123,530	125,750
20	1965-66	1,320	1,490	1,160	1,560	1,510	10,240	22,950	8,520	1,960	414	137	99	10,894	33,844	34,080
21	1966-67	160	878	1,620	9,770	6,140	8,880	15,220	55,950	37,280	3,560	415	255	96,790	112,010	112,680

Figure 5-4.--Streamflow data tabulation.

RESERVOIR: UNITY (NEAR UNITY, OREGON) Std. No. 1415
Location: Baker County, Sec. 22 and 27, T. 12 S., R. 37 E.
Storage capacity: 25,260 acre feet
Type of Dam: Earth
Height: 76 feet

Records available: March 1938 to date

Remarks: Storage began February 19, 1938

Yrs. of Record	Year	Oct. 31	Nov. 30	Dec. 31	Jan. 31	Feb. 28	Mar. 31	Apr. 30	May 31	June 30	July 31	Aug. 31	Sept. 30
1	1938						12,860	13,790	13,430	12,370	10,420	7,294	3,432
2	1938-39	4,200	6,570	8,592	10,030	11,750	20,950	25,400	21,730	17,960	13,930	8,964	6,625
3	1939-40	5,790	6,335	7,114	8,050	11,980	25,220	25,220	20,680	15,910	12,190	7,344	5,312
4	1940-41	7,634	9,222	10,900	12,400	12,610	20,430	25,220	24,760	23,410	19,750	13,900	13,750
5	1941-42	11,300	11,370	11,570	11,500	11,500	14,480	24,310	25,220	21,990	15,840	10,970	7,228
6	1942-43	7,286	8,536	9,348	9,285	7,460	11,980	25,120	25,030	21,730	16,300	10,900	5,574
7	1943-44	6,060	5,468	3,698	5,156	7,002	12,050	18,340	16,070	15,370	10,370	5,000	1,960
8	1944-45	3,120	5,844	8,536	10,440	11,700	13,320	20,430	24,580	19,750	15,300	8,908	4,600
9	1945-46	3,974	5,952	8,722	11,230	11,630	14,780	22,350	23,770	18,670	13,970	8,050	4,452
10	1946-47	4,600	6,445	9,920	8,110	11,910	24,130	25,220	20,600	15,600	10,240	4,950	590
11	1947-48	1,320	3,252	3,560	4,550	7,460	11,980	19,080	24,580	23,680	17,070	11,770	7,870
12	1948-49	5,052	6,834	8,350	8,536	8,474	12,960	23,410	23,770	18,180	13,030	6,722	2,284
13	1949-50	653	1,104	1,654	2,440	3,380	6,335	20,770	23,950	20,430	14,700	10,040	5,630
14	1950-51	5,104	5,844	7,114	8,910	12,470	14,700	23,320	23,410	18,420	13,540	7,230	2,960
15	1951-52	2,480	3,296	4,550	5,420	5,900	6,950	16,840	24,130	19,580	13,030	6,720	3,040
16	1952-53	1,350	1,960	2,960	5,680	8,600	14,780	25,220	25,030	23,590	17,300	11,030	5,790
17	1953-54	1,650	1,440	2,030	3,430	8,470	15,370	25,220	20,600	18,590	14,420	8,410	3,840
18	1954-55	1,320	2,030	2,520	2,520	3,120	4,310	13,030	15,370	9,730	4,950	222	0
19	1955-56	870	1,890	11,700	12,440	12,960	18,260	24,560	24,850	20,170	14,120	7,750	3,650
20	1956-57	1,600	2,480	6,060	9,220	15,370	21,780	24,400	23,770	17,860	10,840	4,850	1,160
Total	(1943-57)	46,439	62,375	90,722	107,367	135,906	203,685	327,310	339,510	281,350	199,180	112,552	53,400
Average	(1943-57)	3,096	4,158	6,048	7,158	9,060	13,579	21,821	22,634	18,757	13,279	7,503	3,560
21	1957-58	3,970	5,160	5,790	6,500	12,260	12,120	22,120	23,820	20,600	15,370	8,410	3,250
22	1958-59	2,360	3,840	6,830	9,540	12,610	19,160	25,170	22,560	17,460	11,570	4,550	1,380
23	1959-60	1,100	1,910	3,160	5,100	7,000	17,800	25,570	22,940	16,530	10,040	4,040	1,310
24	1960-61	1,430	4,210	6,120	7,810	11,600	18,840	25,640	18,950	13,780	7,460	2,230	622
25	1961-62	1,200	3,210	5,570	8,600	11,610	16,340	25,720	21,440	16,450	10,880	4,970	966
26	1962-63	2,270	5,340	9,220	11,290	19,580	24,720	25,840	24,240	19,050	13,130	6,390	2,090
27	1963-64	1,570	4,020	6,340	8,850	11,010	13,670	25,220	22,810	22,960	16,820	10,770	4,920
28	1964-65	4,450	6,280	14,310	19,940	18,580	21,440	24,600	25,250	20,170	14,190	11,140	6,970
29	1965-66	6,140	7,460	8,880	11,880	13,610	19,650	25,350	18,130	14,260	8,970	3,770	732
30	1966-67	1,688	3,951	6,628	9,728	12,680	17,908	24,472	24,688	19,625	13,984	8,230	3,164
Total	(1953-67)	32,968	55,181	98,118	132,528	179,060	256,148	362,132	334,448	270,825	184,044	96,762	39,844
Average	(1953-67)	2,200	3,680	6,540	8,840	11,940	17,080	24,140	22,300	18,060	12,270	6,450	2,660

Figure 5-5.--Reservoir data tabulation.

Table 5-1.--Base flow values--Similkameen River near Nighthawk, Washington

[Readings taken the first day of each month]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs	Cfs
1943	370	400	460	520	410	540				8,500	1,800	680
1944	400	500	420	340	300	320				3,400	800	470
1945	520	550	500	400	440	540				3,900	900	400
1946	470	1,100	800	640	500	520				4,800	1,250	550
1947	420	550	500	380	410	520				2,650	1,050	470
1948	420	900	680	560	440	460				5,500	2,100	2,300
1949	1,300	1,000	800	640	600	580				3,300	1,320	620
1950	600	1,000	2,000	940	660	720				10,000	2,200	830
1951	580	800	1,350	1,550	850	1,200				6,000	1,350	1,000
1952	700	950	660	510	540	490				4,000	1,150	500
1953	350	320	310	300	460	460				5,500	1,350	820
1954	780	650	800	700	600	600				11,500	2,900	1,700
1955	1,250	1,030	1,850	1,000	680	520				9,000	2,800	730
1956	570	1,500	1,150	840	660	580				5,800	1,400	850
1957	620	930	770	920	650	650						
1958		520										
1959		640										
1960		2,450										
1961		540										
1962		510										
1963		550										
1964		1,170										
1965		950										
1966		550										
1967		700										
1968		1,400										
1969		760										

National Oceanic and Atmospheric Administration (NOAA)

The U.S. Department of Commerce's Environmental Data Service of the National Oceanic and Atmospheric Administration publishes by state or group of states monthly and annual summaries of data about precipitation, temperature, evaporation, humidity, and wind in its Climatological Data series. Each snow survey leader should assemble and keep as complete a file as possible of these publications for the state or states in his area of responsibility. The monthly publications give station amounts on a daily basis; the annual summary gives monthly station amounts and calendar-year totals and averages.

Local Climatological Data is a monthly publication of data for approximately 300 stations of the National Weather Service, another major component of NOAA. It contains all the measurements taken at a station on a daily basis as well as showing accumulation of rainfall in hourly amounts. For some stations, a number of observations are listed at 3-hour intervals. There is also an annual summary prepared for the same stations.

Precipitation.--Figure 5-6 shows a tabulation of precipitation data. These data are tabulated by monthly amounts on a water-year basis. Seasonal periods important in forecasting may be totaled at the right of the table.

Temperature.--Temperatures are recorded at many National Weather Service stations and at those of cooperators. Usually the daily maximum and minimum air temperatures are published. Upper-air temperatures are taken at a few National Weather Service stations, and the data are published in the Climatological Data series and in the national summaries. Upper-air temperatures for selected stations can be requested from the National Climatic Center, Federal Building, Asheville, N.C. 28801. This center is the collection center and custodian of all U.S. weather records.

Evaporation.--The Bureau of Reclamation and the International Boundary Commission have published some data, but the Climatological Data series is the principal source.

Humidity and Wind.--Surface- and upper-air data for many National Weather Service stations are available in the Climatological Data series and in other publications. The National Climatic Center in Asheville provides upper-air wind data upon request.

Special Records

Often special records are required that are not available from any published source. These include such data as number of days above or below a given cubic feet per second (cfs) flow, evapotranspiration, net radiation, area-elevation curves, and canopy cover. Hydrology handbooks provide information on compilation and computation procedures.

Coding and Punching Data

All snow course and aerial marker data should be punched on 80-column IBM cards. A detailed description of the procedure follows. Figure 5-7 shows an IBM snow survey data card.

PRECIPITATION STATION: BAKER FAA AP (#0412) Records available: May 1943 to date

LOCATION: BAKER COUNTY, Lat. 44°50', Long. 117°49'

ELEVATION: 3368'

Yrs. of Record	Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
	*	.74	1.01	1.26	1.17	1.06	1.07	.97	1.38	1.17	.51	.52	.74
	**	42	42	42	41	41	41	41	41	41	42	42	42
1	1943								.40	1.53	.34	.32	.02
2	1943-44	1.08	.50	.45	.26	.59	.40	.50	1.27	2.60	.23	.05	.12
3	1944-45	.17	.93	.32	.81	.62	.44	.37	2.35	1.55	T	.48	.80
4	1945-46	.32	.97	.86	.56	.59	.79	.32	2.43	1.00	.43	.62	.42
5	1946-47	.81	.92	.63	.66	.34	.69	.64	1.00	1.77	T	.01	.66
6	1947-48	1.67	.92	.40	.44	.73	1.32	1.28	2.34	2.02	.55	.46	.28
7	1948-49	.51	.95	1.50	.33	.88	.63	.71	1.60	.15	.16	.14	.51
8	1949-50	.19	1.26	.44	.96	.15	.70	.64	.04	2.23	.45	.52	.05
9	1950-51	.84	.46	.46	1.04	.51	.87	.31	.79	.32	.14	.53	.03
10	1951-52	.77	.92	1.23	.90	1.25	.49	1.18	2.03	2.06	.04	.02	.60
11	1952-53	.02	.44	.75	1.38	1.37	.71	1.24	3.80	1.83	T	.87	.01
12	1953-54	.63	.67	.83	.45	.67	.54	.68	1.05	.92	.25	1.11	.23
13	1954-55	.25	.30	.66	.57	.59	.54	.98	.69	.39	1.10	.00	.82
14	1955-56	1.12	1.55	1.97	1.03	1.07	.38	.39	3.03	1.33	1.90	.44	.08
15	1956-57	1.64	.16	.79	.90	.92	1.93	.42	1.74	1.26	.19	.18	.40
16	1957-58	2.18	.75	1.22	.69	.61	.62	1.23	1.06	3.45	.37	.26	.40
17	1958-59	.35	.76	.93	.51	.49	1.02	.41	1.23	.66	.16	1.28	2.32
18	1959-60	.38	.27	.26	.91	.80	1.14	.60	3.01	.14	.29	.40	.71
19	1960-61	.20	1.75	.43	.21	.90	.67	.21	1.93	.70	.02	.36	.41
20	1961-62	.75	1.51	1.16	1.46	.75	.67	.89	2.20	.04	.04	.35	.97
21	1962-63	1.56	1.08	1.00	1.00	.67	.44	.69	1.26	1.61	.03	.63	.58
22	1964-65	.26	.50	2.83	1.90	.17	.66	1.73	.18	1.19	.62	2.05	.10
23	1965-66	.11	.82	.26	.55	1.17	.93	.19	.57	1.34	.40	.11	.87
24	1966-67	.35	1.13	1.69	.70	.21	1.29	1.37	1.16	1.03	.10	.06	.40
25	1967-68	1.26	.54	.63	.41	.85	.84	.30					

*Means or extremes for the period of record prior to 1931.
**Number of years' record used to obtain means.

Figure 5-6.--Precipitation data tabulation.

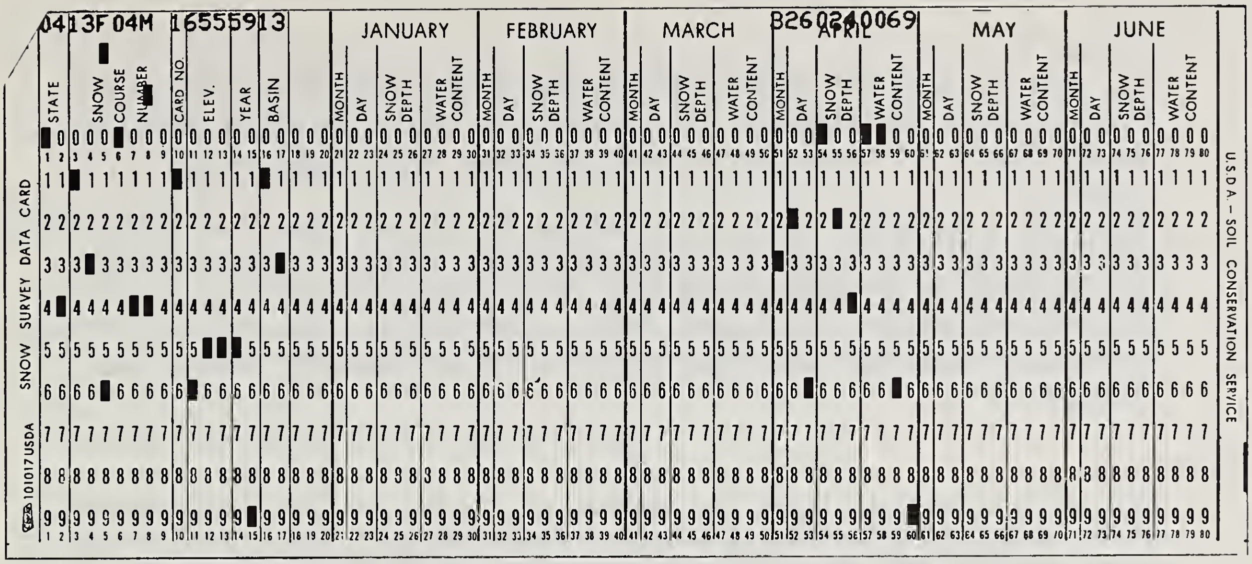

Figure 5-7.--IBM snow survey data card.

Columns 1 and 2:

Code for state in which snow course is located as follows:

01	Arizona	08	Oregon
02	California	09	Utah
03	Colorado	10	Washington
04	Idaho	11	Wyoming
05	Montana	12	South Dakota
06	Nevada	13	British Columbia
07	New Mexico	14	Alaska

Columns 3 to 9:

Punch the snow course index number in these columns as follows: (Special instructions for punching British Columbia snow course records will be sent to interested state offices).

Columns 3 and 4:

Use for the first two digits of the index number that correspond to the last two digits of the meridian to the east of the snow course.

Column 5:

Punch the letter corresponding to the appropriate latitude block. Use the letter "A" in column 5 for all snow courses between 49^{o} and 48^{o}. Similarly, use "B" in column 5 for snow courses between 48^{o} and 47^{o}.

Columns 6 and 7:

Use these columns for the snow course number within the latitude and meridian reference square. Code a single digit as 01, 02, 03, etc. by using a zero in column 6 and a digit in column 7.

Column 8:
Use this column for coding a soil moisture station at the snow course site. For example, if there is no soil moisture station, leave blank; if there is a soil moisture unit, code as M.
Column 9:
Use this column for coding an aerial marker at the snow course site. For example, if there is no aerial marker, leave blank; if an aerial marker is present but not on the snow course, code as 2; if an aerial marker is present at the snow course, code as A. If there is no soil moisture station, only an aerial marker, use column 8 instead of 9.

Column 10:
Use this column to code the number of cards for the individual year. Code all first-of-the-month measurements on a single card in column 10 as "1." Code mid-month measurements on a single card in column 10 as "2." Code special measurements on a third card in column 10 as "3," "4," "5," etc.

Columns 11 to 13:
These columns are for coding the elevation of the snow courses in hundreds of feet to the nearest 10 feet. Thus, a snow course at the following elevations is coded as:

Elevation (feet)	Columns 11	12	13
50	0	0	5
231	0	2	3
9,790	9	7	9
10,000	A	0	0
10,231	A	2	3
11,000	B	0	0
11,561	B	5	6

Leading and following zeros must be punched. In column 11, an "A" punch indicates 10,000 feet and a "B" punch 11,000 feet.

Columns 14 and 15:
Code the year of measurement by using the last two digits of the year, i.e., code 1959 as 59.

Columns 16 and 17:
Code basin of snow course as follows:

06 Upper Missouri
07 Arkansas
08 Rio Grande
09 Colorado
10 Great
11 California and Pacific Coastal
12 Lower Columbia (below mouth of Snake)
13 Snake
14 Upper Columbia (above mouth of Snake)
15 North Pacific Coastal
16 North and South Platte
17 Hudson Bay

Columns 18 to 20:
Leave these columns blank for further use.

Columns 21 to 30:
Code measurement for January 1 as follows:

Column 21:
Enter the exact month of measurement; thus a December 30 measurement is coded in column 21 as 12 (or as the letter K, using the "11 punch" and a (2) punch), even though it is used as the January 1 measurement and it is entered under January on the card.

Columns 22 and 23:
Code the exact day of measurement.

Columns 24 to 26:
Code snow depth in even inches. Code a zero in column 24 if snow depth is less than 100 inches and zeros in columns 24 and 25 if snow depth is less than 10 inches, e.g.,

Snow depth (inches)	Columns 24	25	26
95	0	9	5
5	0	0	5

Columns 27 to 30:
Code water content to tenths of an inch. Code a zero in column 27 if water content is less than 100 and zeros in columns 27 and 28 if water content is less than 10 inches, e.g.,

Water content (inches)	Columns 27	28	29	30
34.0	0	3	4	0
3.4	0	0	3	4

If measurements are estimated or from aerial markers, use "11 punch" in columns 27, 37, or the appropriate month column.

Code months as follows:

1 January	6 June
2 February	7 July
3 March	8 August
4 April	9 September
5 May	

Letter (Ø) punch for October
"11 punch" and a (1) punch for November (Letter "J")
"11 punch" and a (2) punch for December (Letter "K")

Columns 31 to 80:

These columns are coded if needed. On the sample card (fig. 5-7) the following snow course measurement is indicated in ink in the proper spaces.

		Coded	Card columns
State	Idaho	04	1 and 2
Snow course	Garfield R.S. 13F4	13F04M	3 to 9
Card number		1	10
Elevation	6,554 feet	655	11 to 13
Year	1959	59	14 and 15
Basin	Snake	13	16 and 17
Month	March**	3	51
Day	26	26	52 and 53
Snow depth	24 inches	024	54 to 56
Water content	6.9 inches	0069	57 to 60

**Note that these data are in columns 51 to 60. Even though actual measurements were made on March 26, the data are used as first-of-month measurement in April.

Publication of Data Summaries

Data summaries can be prepared readily from the snow survey data decks. New summaries including supplemental data should be prepared and published every 5 years.

Most local data processing centers can handle this work. Figure 5-8 is an example of an IBM listing that was used with cartographic additions in a snow survey summary.

Data from Automatic Data Sites

A pressure pillow and the related instruments at automatic data sites, as well as the telemetry system, have the capability of producing vast amounts of data compared with manual observations. The maximum rate of observation is expected to be once or twice a day at most data sites. Observations at more frequent intervals are made for special studies and at key stations. A system of automatic data recording and data retrieval must be used.

Most sensing and telemetering systems are designed to provide one to six parameters per observation, among which are snow water equivalent, precipitation, and temperature. The data from the field or remote station are sent to the base station on a programmed automatic and on-call basis. Basic data are digitized at the data collection site or at the base station before recording. If the data are first recorded in an analog form, they are converted to a digital form, along with corrections, during a phase of computer processing.

Recording

Numerous recording devices are available commercially that can be used in base station configurations. The most practical device seems to be one that prints a hard copy of each reading and at the same time punches the raw data on a paper tape. The 7- or 8-channel paper tape is desirable to provide a parity check.

SNOW COURSE BEAR CREEK STATE OF NEVADA

SNOW COURSE NUMBER 15H01MA ELEVATION 7800

BASIN SNAKE SUB BASIN SNAKE RIVER

LOCATION SEC. 31, T 46N, R 58E HUMBOLDT NATL FOREST

ESTABLISHED 1932, REVISED 1947

SAMPLE POINTS 14 AT 100 FOOT INTERVALS

YEAR	JANUARY 1			FEBRUARY 1			MARCH 1			APRIL 1			MAY 1		
	DATE	(inches) SNOW DEPTH	(inches) WATER CONTENT	DATE	(inches) SNOW DEPTH	(inches) WATER CONTENT	DATE	(inches) SNOW DEPTH	(inches) WATER CONTENT	DATE	(inches) SNOW DEPTH	(inches) WATER CONTENT	DATE	(inches) SNOW DEPTH	(inches) WATER CONTENT
1932							3-09	52	13.0						
1933							3-07	43	13.1						
1934							3-02	45	13.4						
1935							3-02	46	13.8						
1936							2-27	67	21.6						
1937							3-03	46	15.5						
1938							3-04	54	16.5						
1939							3-08	57	16.3						
1940							3-06	50	15.4						
1941							3-04	48	13.8	3-31	47	14.1			
1942							3-02	58	17.9	4-01	58	23.1			
1943							2-25	59	22.1						
1944							3-02	53	14.5						
1945							3-03	58	13.8	4-04	78	21.0			
1946							2-27	48	16.4	4-03	64	22.0			
1947							2-24	42	12.6	3-28	46	15.0			
1948							3-03	54	14.3	4-02	62	20.0			
1949							3-25	64	23.0	3-30	77	24.4			
1950							2-28	50	17.8	3-31	67	23.0			
1951							2-28	56	18.0	4-01	65	22.8			
1952							2-28	74	24.3	3-27	95	33.1			
1953										3-21	59	19.9			
1954										3-29	48	12.1			
1955	12-29	16	3.4	2-01	38	9.2	3-02	46	13.0	3-31	51	17.2	5-01	57	21.8
1956	1-03	36	11.8	2-01	55	18.0	3-02	65	22.7	3-30	56	23.1	5-01	43	19.4
1957	12-29	33	8.9	1-28	49	12.8	2-27	54	16.5	3-29	69	23.3	5-01	62	24.4
1958	1-02	30	7.6	1-28	47	12.1	2-27	69	18.4	3-27	68	23.4	4-28	62	25.4
1959	12-29	21	5.0	1-28	47	10.7	2-25	52	15.8	3-27	52	18.8	4-28	31	14.0
1960	12-29	19	4.7	1-26	29	7.5	2-24	47	13.5	3-28	52	19.4	4-26	42	18.3
1961	12-29	21	6.2*	2-01	24	6.6*	2-28	41	9.4	3-26	56	14.9	4-28	35	12.6*

*AERIAL SNOW DEPTH READING; WATER CONTENT ESTIMATED.

MISCELLANEOUS

1934	3-12	41	12.3

Figure 5-8.--Data summary prepared from IBM listing, with cartographic additions.

An example of hard copy printout follows:

SAMPLE OUTPUT

40	TIME	CAL.	WATER-IN.		PRECIP.-IN.		TEMP.	DEG.
765	622	899	348(1)	17.41(2)	352(1)	31.59(2)	486(1)	19.98(2)
890	922	899	349	17.47	353	31.71	483	19.59
973	1121	899	351	17.59	354	31.83	477	18.81

40 - Day. 765 - Decimal time. 622 - 12-hour clock time P.M.
899 - Calibration check (1) transmitted readings, (2) converted values in inches or degrees.

Permanent Storage

Once the data are recorded on paper tape, the next step is to place them on a recording medium that is more suitable for computer processing and storage. The most logical storage medium is magnetic tape because it has a capacity for high data density, is economical to process, and is durable and reusable.

Devices are available that convert data on paper tape to cards or magnetic tape or both. There are advantages to using cards as an intermediate process for placing the data on magnetic tape. This intermediate use of cards allows for sorting the data by station, date, and time for serial listing on the magnetic tape. Thus, for any given period all the data for a particular station are loaded on a consecutive section of tape. This reduces processing time for tape searching and mounting.

All data transmitted should be recorded until the reading frequency has been determined. Automatic data stations are identified by a three-digit number. The standard numbering system cannot be used in automatic data processing.

In recording, a computer program corrects all basic data for any constant error in sensing or transmitting not corrected on prior processing. A computer program also is needed to select data recorded on the tape for processing. A duplicate magnetic tape should be prepared before the paper tape or the conversion cards are destroyed.

CHAPTER 6. WATER SUPPLY FORECASTING

CONTENTS

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CHAPTER 6. WATER SUPPLY FORECASTING

Theory

Water supply forecasting is a complex technique that utilizes snow survey and other related information to predict seasonal (spring-summer) streamflow and other streamflow factors such as peak, date of peak, and number of days above a specified level.

A major part of the annual flow of most streams in western United States occurs during the spring and summer months. The principal source of this part of the flow is the melting snow that accumulates each winter on high mountain watersheds.

The ratio of seasonal streamflow to annual flow is always high but varies from stream to stream and from year to year. The seasonal streamflow from April through September or from April through July occurs during the period of least precipitation and greatest need for irrigation water.

In addition to having a broad knowledge of water use practices in the basins for which forecasts are made, a water supply forecaster must have a working knowledge in several scientific fields--engineering, physics, chemistry, geology, hydrology, forestry, meteorology, statistics, and automatic data processing. Using pertinent information in these fields, a forecaster analyzes and further refines streamflow, snow water equivalent, soil moisture, precipitation, base flow, temperature, and other data to develop water supply forecast procedures.

Procedure

A water supply forecast procedure is an adaptation of the basic hydrologic equation: $R = P - L$, where R is runoff, P is precipitation (snow or rain), and L is losses. It is necessary to adapt or translate this equation into individual water supply forecast equations, each of which is unique to a specific stream, forecast point, and time period.

It is virtually impossible except in <u>densely</u> instrumented watersheds to measure precipitation (P) and losses (L) quantitatively. Therefore, the basic equation, $R = P - L$, is modified to the following form:

$$R = PI - LI \qquad \text{Equation (1)}$$

where

R is runoff
PI is a precipitation index
LI is a loss index

Equation (1) imposes a time (years of record) requirement. A forecaster uses a limited number of index variables with several years of record (usually 15 or more) in contrast to the basic hydrologic or water balance equation that utilizes many variables with a few years of record.

An algebraic example of the basic final form assumed by Equation (1) after a detailed statistical analysis is:

$$Y = \pm a + b_{bf}BF + b_{fp}FP + b_{swe}S + b_{sp}SP \qquad \text{Equation (2)}$$

where Y is the runoff in acre-feet for a specific station for a given time period

a is a constant

b_{bf} is a base flow coefficient for weighting a base flow variable (BF).

b_{fp} is a fall precipitation coefficient for weighting a fall precipitation variable (FP).

b_{swe} is a snow water equivalent coefficient for weighting a snow variable (S).

b_{sp} is a spring precipitation coefficient for weighting a spring precipitation variable (SP).

Significance of Forecasting Variables

Many interrelated variables are used in forecasting (ch. 2). Table 6-1 gives a brief resume of source, use, and relative significance of the principal forecasting variables.

Snow Water Equivalent

Currently there are about 1,900 snow courses in western United States and Canada. Records date back to the early 1900's on a limited number of these snow courses. Most have records beginning in the late 1930's and early 1940's.

Figure 6-1 shows the variability of snow water equivalent at a typical western snow course. Only part of the historical record is shown. Note that snow water equivalent at Diamond Lake Snow Course ranged from an April 1 maximum of 40.7 inches to an April 1 minimum of 6.7 inches.

Depending on factors such as elevation, aspect, cover, latitude, and year-to-year storm variability, a snow course may reach its seasonal maximum as early as February 15 or as late as June 15. Therefore, the seasonal maximum often is used in lieu of April 1 data.

Table 6-1.--Forecasting variables

Variable	Principal source	Used as	Relation to Runoff	Relation to Peak	Significance	
						Percent
Snow water equivalent	SCS	PI	Positive	Positive	Very high	60-90
Streamflow (antecedent)	USGS	PI	Positive	Positive	Moderate	5-15
Base flow	USGS	PI	Positive	Positive	Moderate	5-15
Soil moisture	SCS	LI	Positive	Positive	Moderate	5-10
Precipitation						
Fall	NOAA & SCS	PI	Positive	Positive	Moderate	5-20
Winter	NOAA & SCS	PI	Positive	Positive	Moderate-high	30-60
Spring	NOAA & SCS	PI	Positive	Positive	Moderate-high	10-25
Temperature	NOAA	LI	Negative	Positive	Moderate-high	10-25
Wind	NOAA	LI	Negative	Negative	Moderate	5-20
Radiation	NOAA	LI	Negative	Negative	Moderate	5-15
Relative humidity	NOAA	LI	Positive	Positive	Moderate	5-10

NOTE: This table is a summary of the relative significance of variables. The significance percentages indicate in broad terms what percentage of the variability accounted for by a multiple regression equation is attributable to a particular variable.

The number of snow courses in a basin may range from as few as five or less in a small basin to more than 550 snow courses in a large basin such as the Columbia River above The Dalles, Oreg. By statistical procedures, which are discussed in further detail in this chapter, data for the most representative snow courses are grouped into a snow index for the basin in question.

Soil Moisture

The amount of spring snowmelt water required to bring the soil to field capacity varies from year to year depending on the amount of fall precipitation before the first heavy snowfall, watershed consumption, and evaporation losses. The amount of water that can be absorbed by the soil varies from basin to basin. Its effect on seasonal runoff is least in the California Sierras where the shallow granitic soils at best absorb only a fraction of the usual 30 to 40 inches of water stored as snow on the watersheds in the spring. The greatest effect is in areas of low precipitation such as Arizona and New Mexico. In these areas, there are years when all available water in the snowpack is absorbed by the soils, leaving little if any snowmelt for immediate runoff.

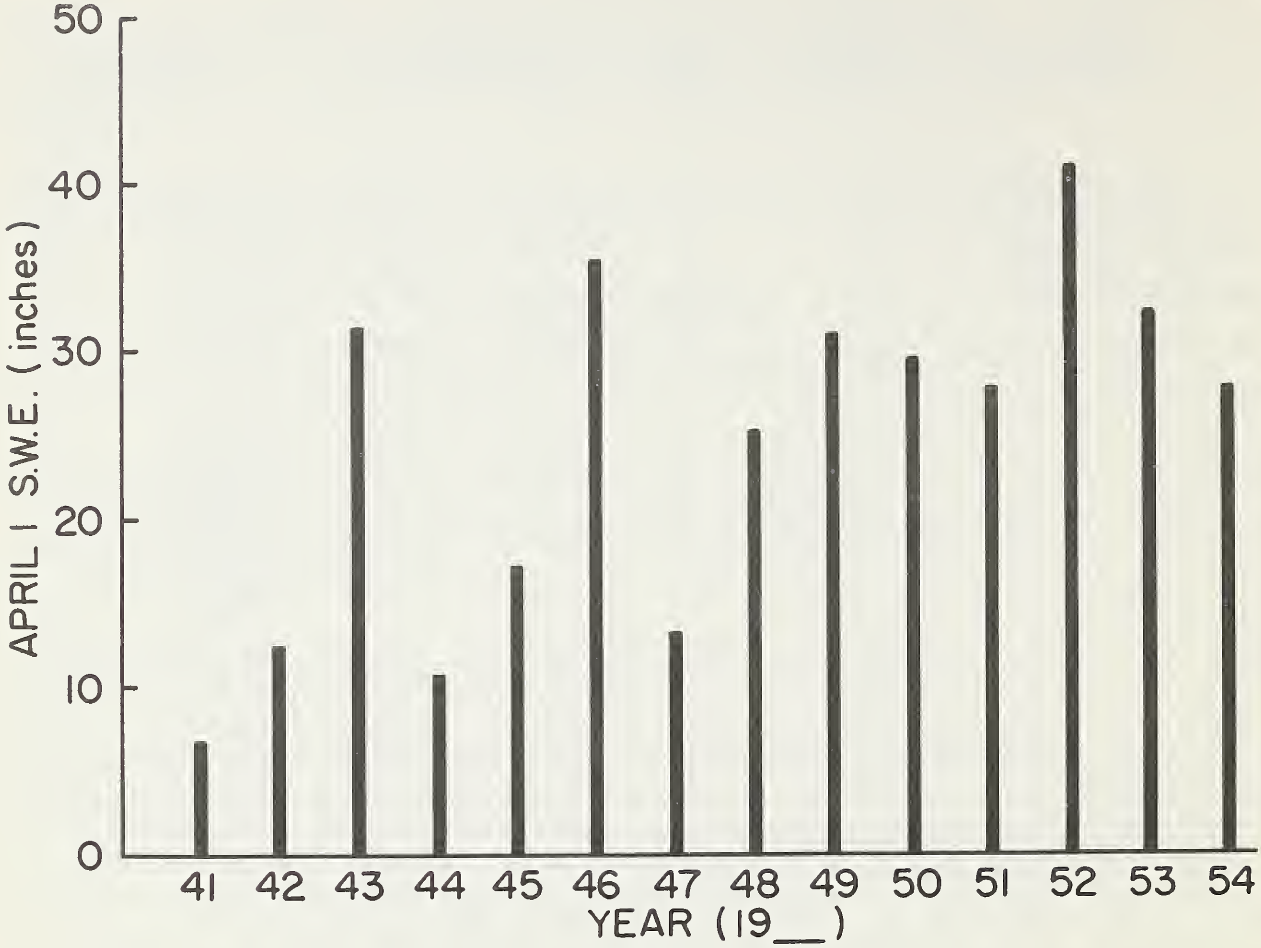

Figure 6-1.--Snow water equivalent--Diamond Lake, Oreg., Snow Course.

Limited historical records have precluded the extensive use of mountain soil moisture data as a forecast variable. Preliminary analyses indicate that soil moisture data are significant in areas where the average snow water equivalent is 15 to 20 inches or less.

Precipitation

Fall precipitation (antecedent) data have been used to index soil moisture conditions. Frequently this index increases the accuracy of forecast relationships. Typically, data for one or more of the months of September, October, and November are used in this index.

Winter precipitation (current) has been successfully used as a forecast index in lieu of snow water equivalent data. Generally this index is not as significant as snow because of the preponderance of precipitation stations at the lower elevations and inaccuracy in gage catch at the higher elevations.

Spring precipitation (subsequent) frequently contributes an important amount to seasonal runoff in addition to the water available in the snowpack. Its effect varies from basin to basin but usually is of greater significance in the Great Basin and the Southwest. The effect of rain falling on bare ground is not the same as that of rain falling on ripe snow. Precipitation falling on dry soil is at least partially absorbed and is not all available for runoff. Precipitation falling on ripe snow lying on wet ground is nearly all available for runoff. Therefore the increase of streamflow due to spring precipitation becomes less and less as the area of the snowpack decreases. The effect of May precipitation on seasonal runoff is often one-half that of April and of that for June is often one-half that of May.

It is not uncommon for spring precipitation to be the second most significant index in a forecast relationship. Unfortunately, the precipitation occurs during the runoff period and cannot be accurately predicted in advance.

Base Flow

Base flow of a stream is that part of the flow that comes from ground-water storage and interflow combined--commonly referred to as ground-water flow. It is assumed that base flow or ground-water flow is derived from precipitation that reaches the deeper aquifers or ground-water bodies, and that forms a greater part of the streamflow during the dry season or between storms. If base flow is used as an index, seasonal runoff forecasts can be adjusted for antecedent streamflow conditions before April 1, the principal forecast date.

Temperature

Temperature data occasionally improve a seasonal runoff forecast. But their principal use is in peak and hydrograph forecasts. The snowmelt rate is controlled in large measure by solar radiation. In lieu of specific radiation values, temperature data often provide a useful index. Upper-air temperature readings (RAWIN) have been successfully used if ground readings at high elevation are lacking.

Wind

Wind data used in conjunction with temperature, radiation, and relative humidity data provide an index that in certain areas increases the accuracy of forecasts. In general, the interaction of these variables indexes evaporation-sublimation losses from the mountain snow cover that are not reflected in snow survey data because of the protected location of snow courses.

Before an acceptable snowmelt runoff forecast relationship can be developed for some streams, an accurate precipitation index corrected for evaporation and sublimation must be computed. In Wyoming it is obtained as follows:

Choose the date at which the maximum snowpack generally occurs (in the Rockies this is May 1). In the years when melt occurs during April, add the April precipitation to the April water content to estimate the water content on May 1.

Combine the water content data (weighted) for snow courses at high, medium, and low elevations to get the best fit with April 1 to September 30 snowmelt runoff in thousands of acre-feet (ASROM). Add the weighted precipitation values for May and June, generally 100 percent for May and 50 percent for June, to the weighted water content data.

Subtract the soil moisture deficit in inches from this sum. The soil moisture deficit can be determined from the soil moisture stack data for April 1. Do not use data for May 1. An alternative source of soil moisture data consists of the weighted precipitation values for August, September, October, and November, generally 50 percent for August, 75 percent for September, and 100 percent for the precipitation that occurs between October 1 and the date of the initial snowpack accumulation. Subtracting the actual soil moisture or precipitation total from the field capacity of the watershed soils gives the soil moisture deficit.

This procedure varies somewhat from one watershed to another and probably varies considerably from one state to another. It is important to get the most accurate precipitation column possible, but large errors are to be expected in plotting the precipitation column. In some watersheds in the Rocky Mountains, the variation in evaposublimation (referring to reasonable variation--not flood-producing spring and summer rains) far exceeds the variation in soil moisture and spring precipitation combined.

Figure 6-2 shows a map of the Smith's Fork watershed. Figures 6-3, 6-4, and 6-5 show how a water column ASROM relationship for the Smith's Fork watershed is developed.

Figure 6-6 shows the wind index curve. In the alpine areas and on the open plateaus, the watershed snowpack suffers losses that do not occur on snow courses protected by forests. To get a measure of these losses, the plus and minus errors from the mean curve of figure 6-5 are plotted against the 750-millibar wind data (approximately 8,200 feet) at Boise, Idaho. Wind is an important factor in determining the rate at which evaporation occurs. The effect of wind decreases from 100 percent during November and April to about 50 percent for December and March and to 10 percent or less for January and February.

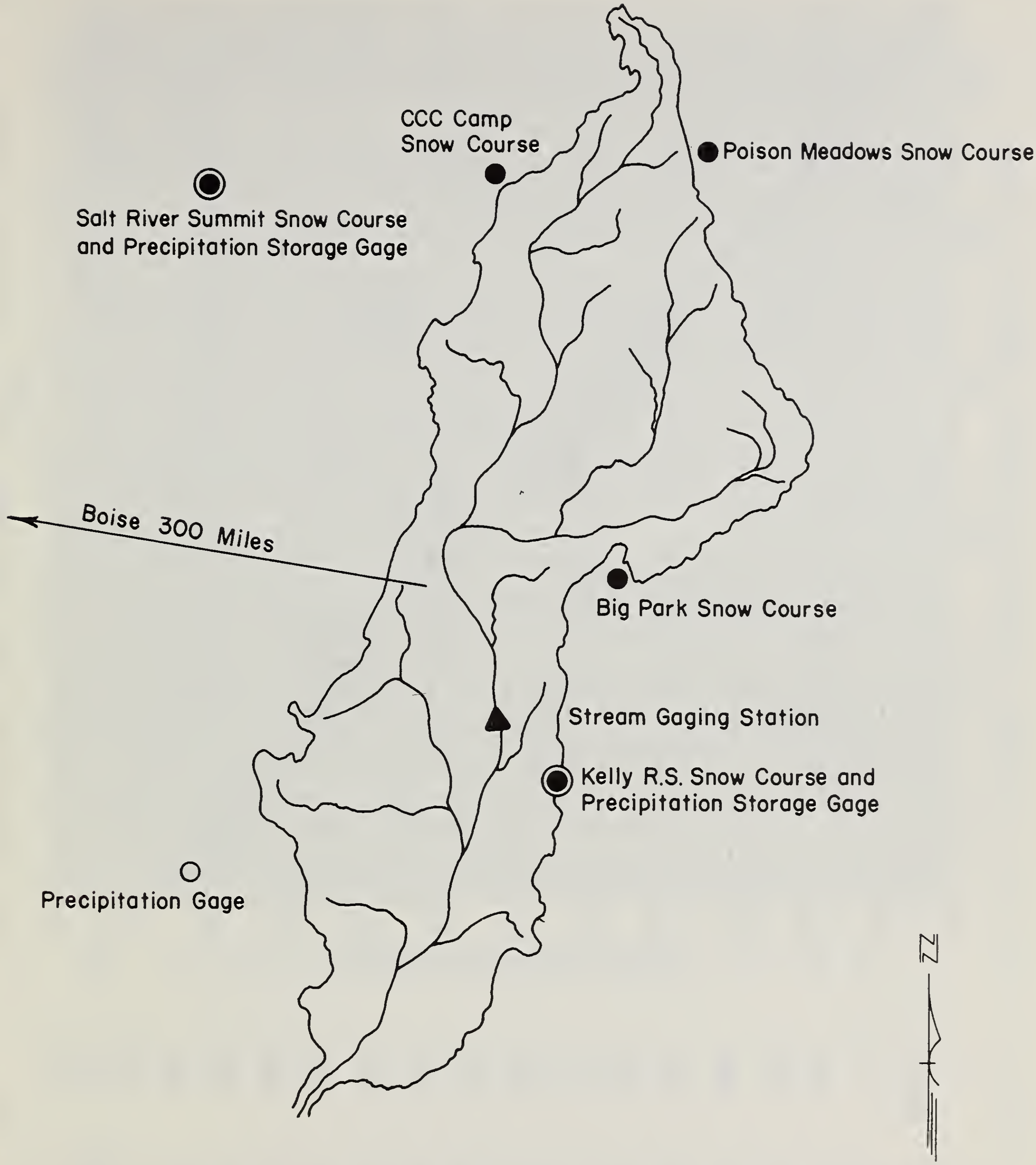

Figure 6-2.--Map of Smith's Fork watershed.

Year	May 1 Snow Course Index	ASROM
1948	21.7	111
1949	22.0	102
1950	29.0	153
1951	31.3	149
1952	27.2	126
1953	21.2	99
1954	26.4	89
1955	19.6	78
1956	34.8	152
1957	26.6	148
1958	25.6	112
1959	22.6	80
1960	20.0	83
1961	16.8	49
1962	31.7	142
1963	22.0	95

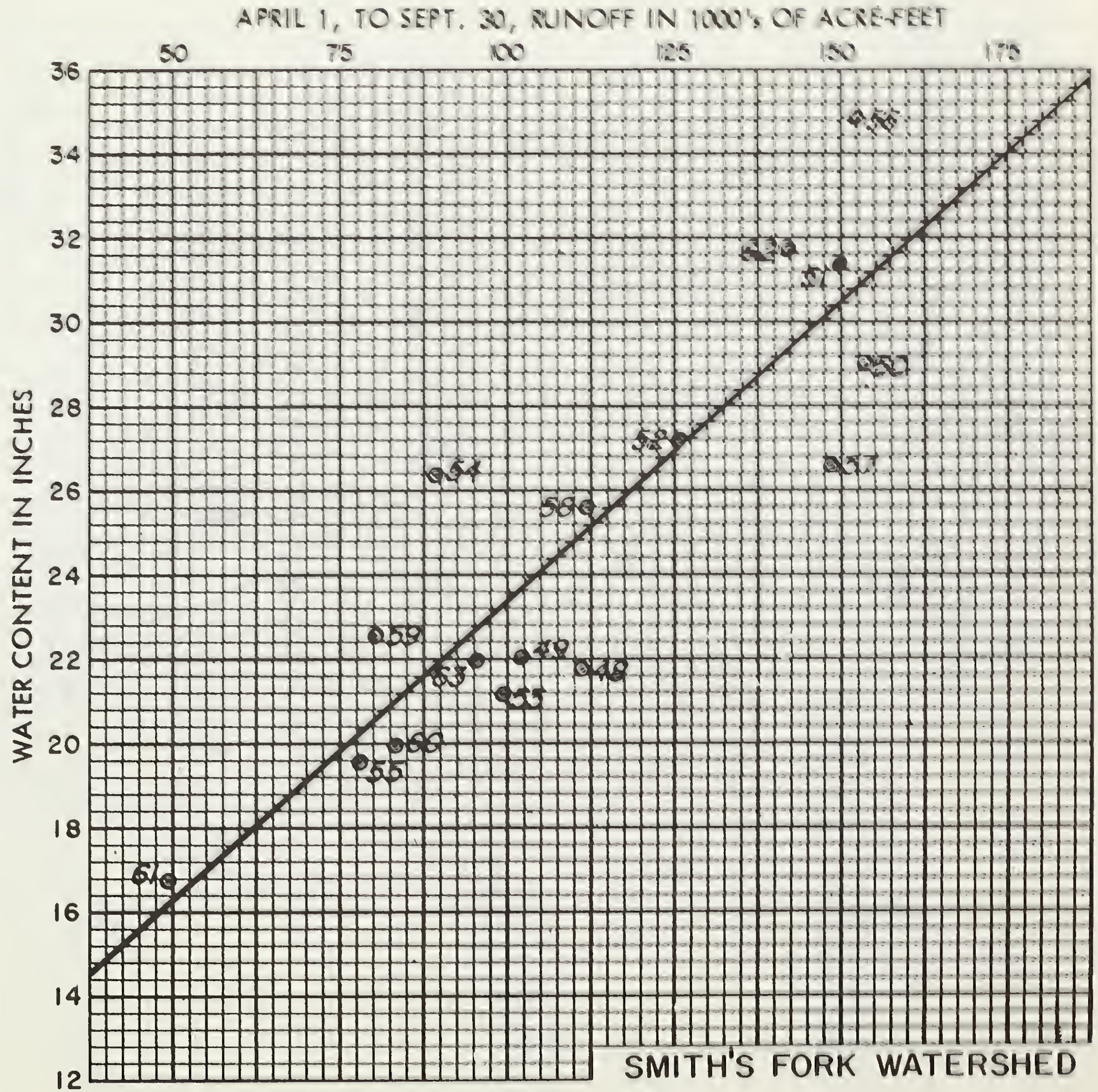

Figure 6-3.--May 1 snow course index versus April-September runoff (1000's acre-feet).

Year	May 1 Snow Course Index	Soil Moisture Deficit	Usable May 1 Snow Course Index	ASROM
1948	21.7	-2.0	19.7	111
1949	22.0	-3.1	18.9	102
1950	29.0	-0.3	28.7	153
1951	31.3	-1.7	29.6	149
1952	27.2	-2.4	24.8	126
1953	21.2	-4.9	16.3	99
1954	26.4	-3.8	22.6	89
1955	19.6	-3.7	15.9	78
1956	34.8	-2.3	32.5	152
1957	26.6	-4.0	22.6	148
1958	25.6	-3.6	22.0	112
1959	22.6	-3.9	18.7	80
1960	20.0	-2.0	18.0	83
1961	16.8	-2.0	14.8	49
1962	31.7	-2.2	29.5	142
1963	22.0	-3.7	18.3	95

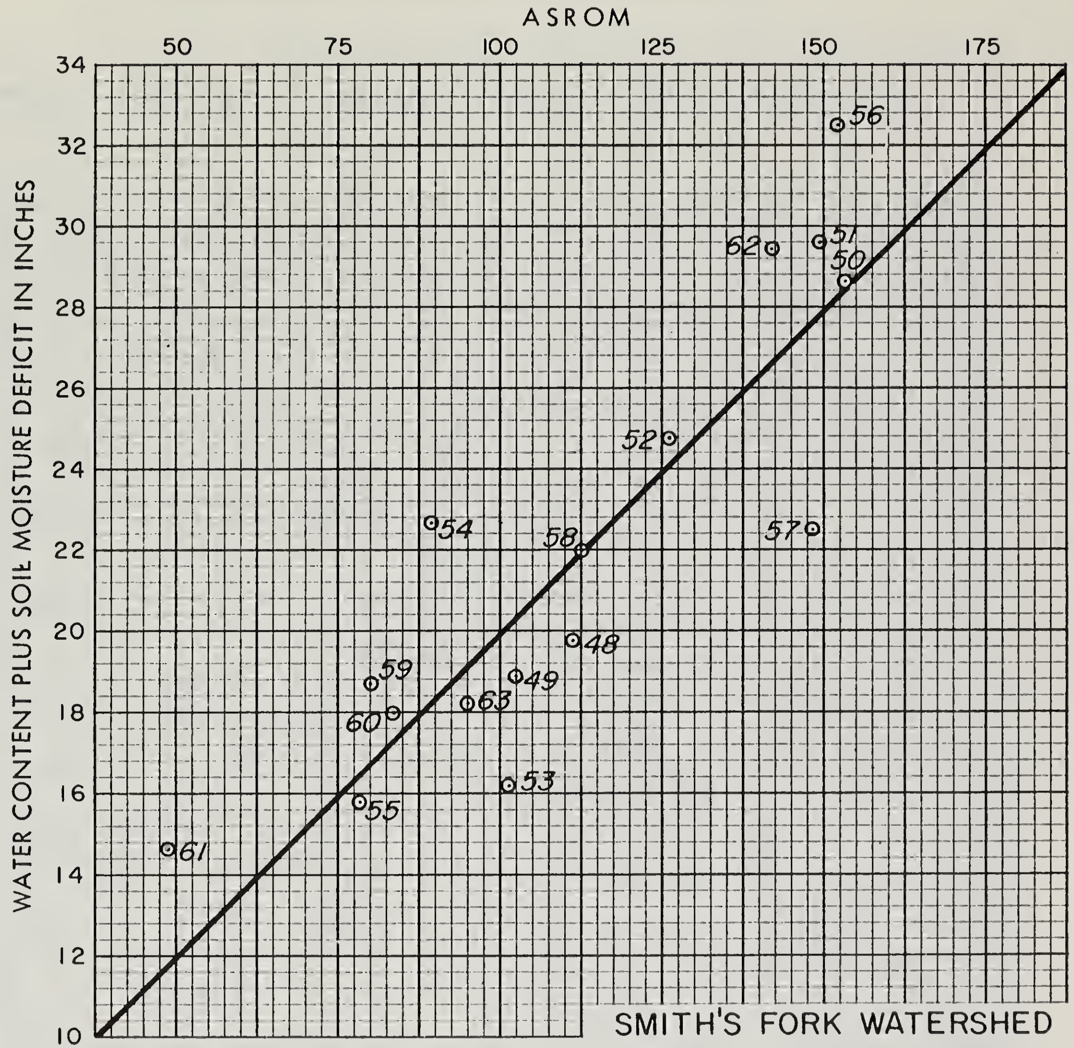

Figure 6-4.--Revised Figure 6-3, soil moisture deficit added.

Year	May 1 Usable Snow Course Index	Mountain Precip. for May	June 1 Usable Snow Course Index	ASROM
1948	19.7	0.6	20.3	111
1949	18.9	1.1	20.0	102
1950	28.7	0.8	29.5	153
1951	29.6	0.6	30.2	149
1952	24.8	0.6	25.4	126
1953	16.3	1.1	17.4	99
1954	22.6	0.7	23.3	89
1955	15.9	0.6	16.5	78
1956	32.5	0.9	33.4	152
1957	22.6	2.1	24.7	148
1958	22.0	0.8	22.8	112
1959	18.7	1.1	19.8	80
1960	18.0	1.0	19.0	83
1961	14.8	0.7	15.5	49
1962	29.5	1.2	30.7	142
1963	18.3	0.7	19.0	95

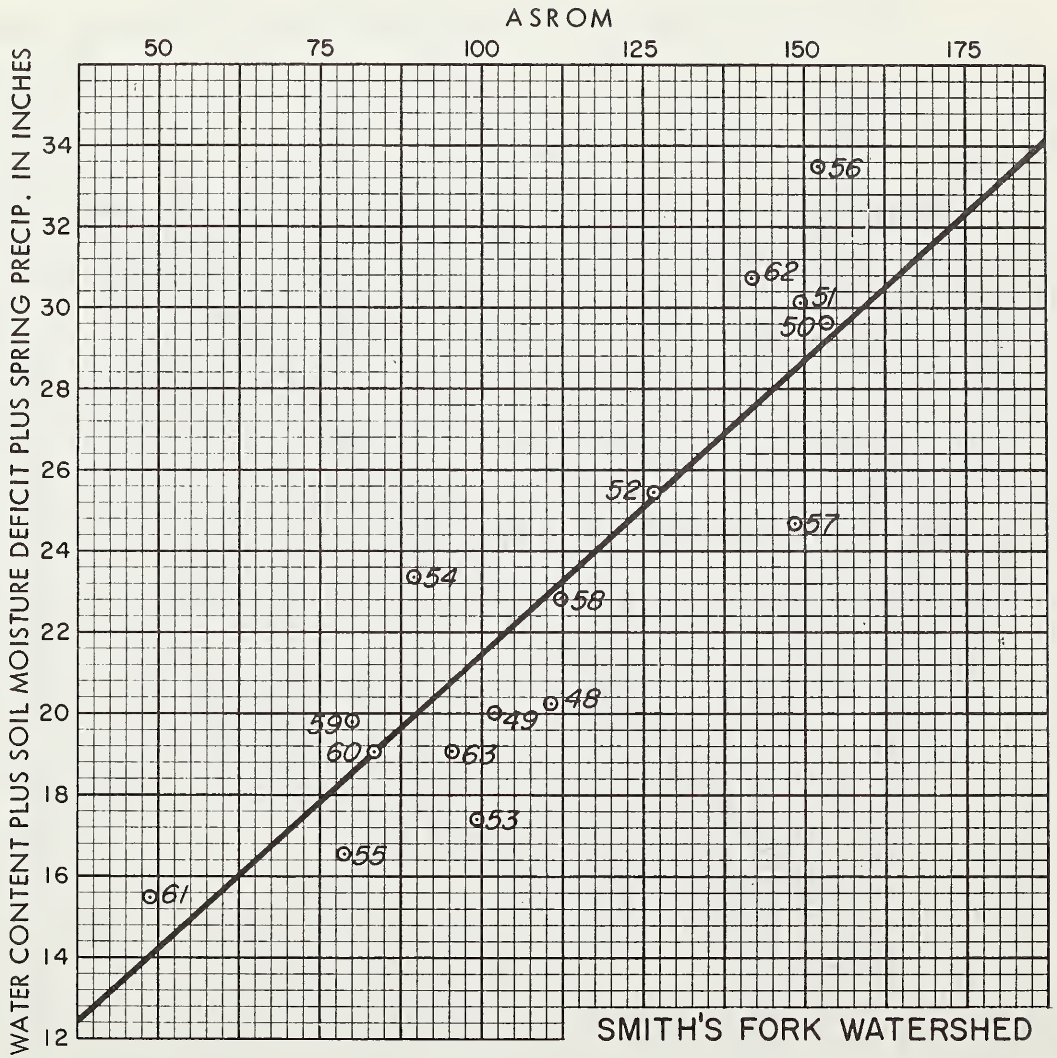

Figure 6-5.--June 1 snow course index versus April-September runoff (1000's acre-feet).

Year	Inches Error from Figure 6-5	Winter Wind Boise 750 mb.
1948	2.8	43.6
1949	1.8	43.5
1950	-0.3	44.4
1951	-1.6	45.9
1952	-0.1	45.8
1953	3.9	40.0
1954	-3.4	45.9
1955	1.5	41.3
1956	-4.3	49.7
1957	3.8	39.0
1958	0.5	43.2
1959	-1.3	45.3
1960	0.1	41.9
1961	-1.4	44.9
1962	-3.0	45.0
1963	1.7	40.3

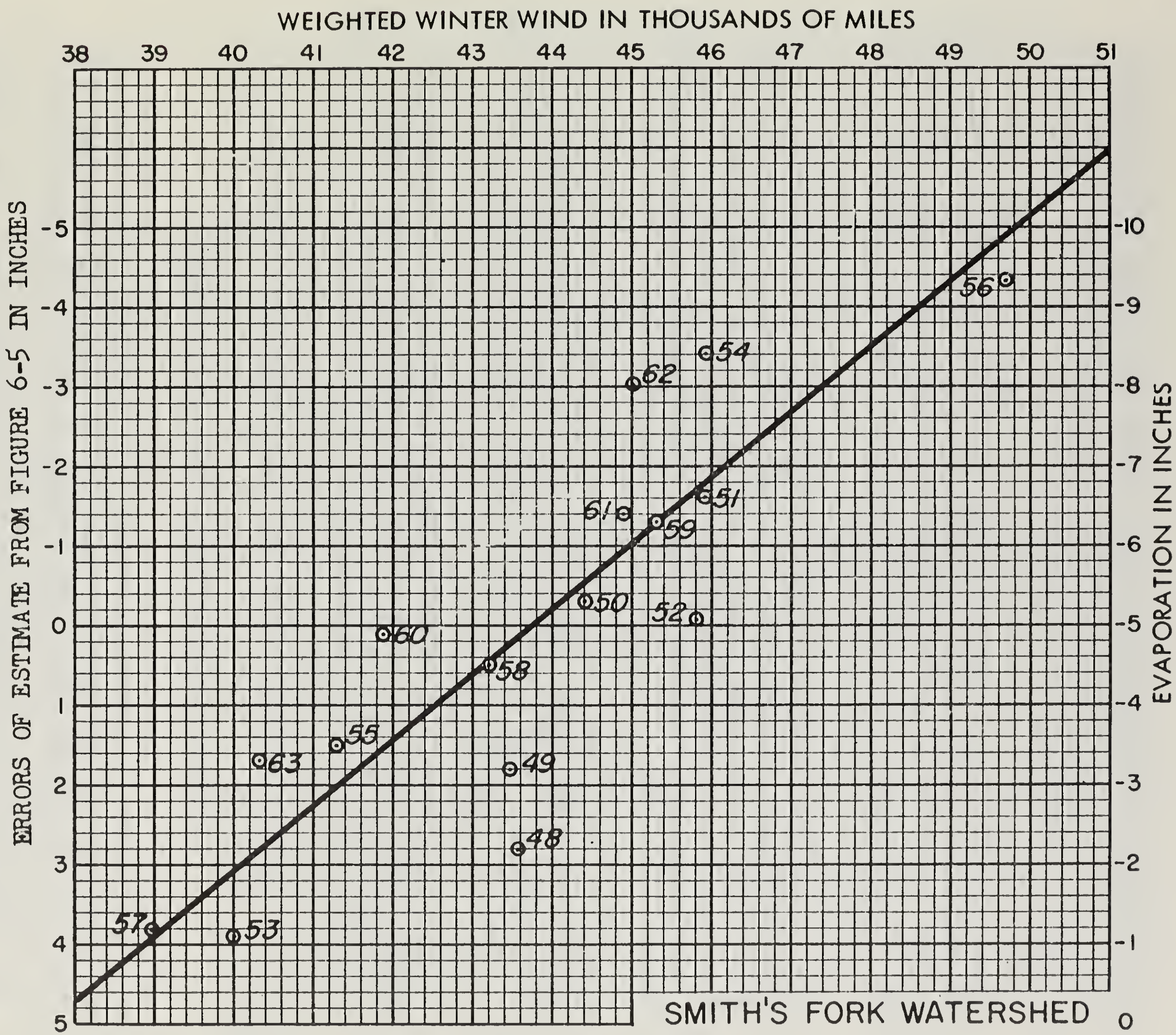

Figure 6-6.--Wind index.

Figure 6-7 shows the temperature index curve. To obtain evaporation values for the air-temperature factor, the plus and minus errors from the mean curve of figure 6-6 are plotted against the total number of degree days from November 1 to April 30.

Figure 6-8 shows another important evaporation factor, solar radiation. The plus and minus errors from the mean curve of figure 6-7 are plotted against the total hours of radiation from November 1 to April 30. This estimate of radiation is obtained by using the monthly percentage of possible sunshine at Lander.

Figure 6-9 shows the snowpack evaporation index. It is assumed that the mean curve of figure 6-6 and the errors from figure 6-5 cover the maximum variation in evaporation range, so the plus and minus values are changed to negative values that range from zero to minus ten. The curve values of figures 6-6, 6-7, and 6-8 are then totaled to get an evaporation index.

For figure 6-10, the June 1 usable snow course index of figure 6-4 is corrected by the evaporation index of figure 6-9 to get an index of the watershed snowpack. The watershed snowpack index is plotted against the ASROM to get the forecast equation for Smith's Fork watershed.

Figure 6-11 shows that the combined evaporation values of temperature and radiation were close to normal for the years 1953, 1956, and 1957. But the wind velocities for 1953 and 1957 were the lowest for the period of record, and those for 1956 the highest.

It may be of some interest to note the wide variation in snowpack evaporation resulting from extreme values for wind velocity in years having normal temperature and radiation evaporation factors.

It is quite possible that there is a limiting velocity for maximum evaporation from the undisturbed surface of that part of the snowpack not protected against the wind. An increase in the wind velocity, however, produces an increase in forest penetration and, therefore, an increase in the exposed area of the snowpack and an increase in evaporation. When velocity becomes high enough to transport snow, the exposed area of the snowpack is increased still more as is, proportionately, the amount of evaporation. It would seem that there is no limiting velocity for maximum snowpack evaporation from most watersheds.

The procedure used to evaluate the wind run is not sound hydrologically, but at this time it is the only method known. The weighted values for wind follow the 16-year average temperature cycle during the 6 winter months, but in any single year it is possible for December or March temperatures to be higher than November or April temperatures. If this occurs, and it has, errors are introduced.

Year	Inches Error from Figure 6-6	Winter Temp. Nov. Thru April
1948	2.7	128
1949	1.6	180
1950	0.2	207
1951	0.2	238
1952	1.6	191
1953	0.8	213
1954	-1.7	280
1955	-0.5	217
1956	0.6	179
1957	-0.1	193
1958	0.1	182
1959	0.0	241
1960	-1.5	251
1961	-0.5	190
1962	-2.0	255
1963	-1.1	226

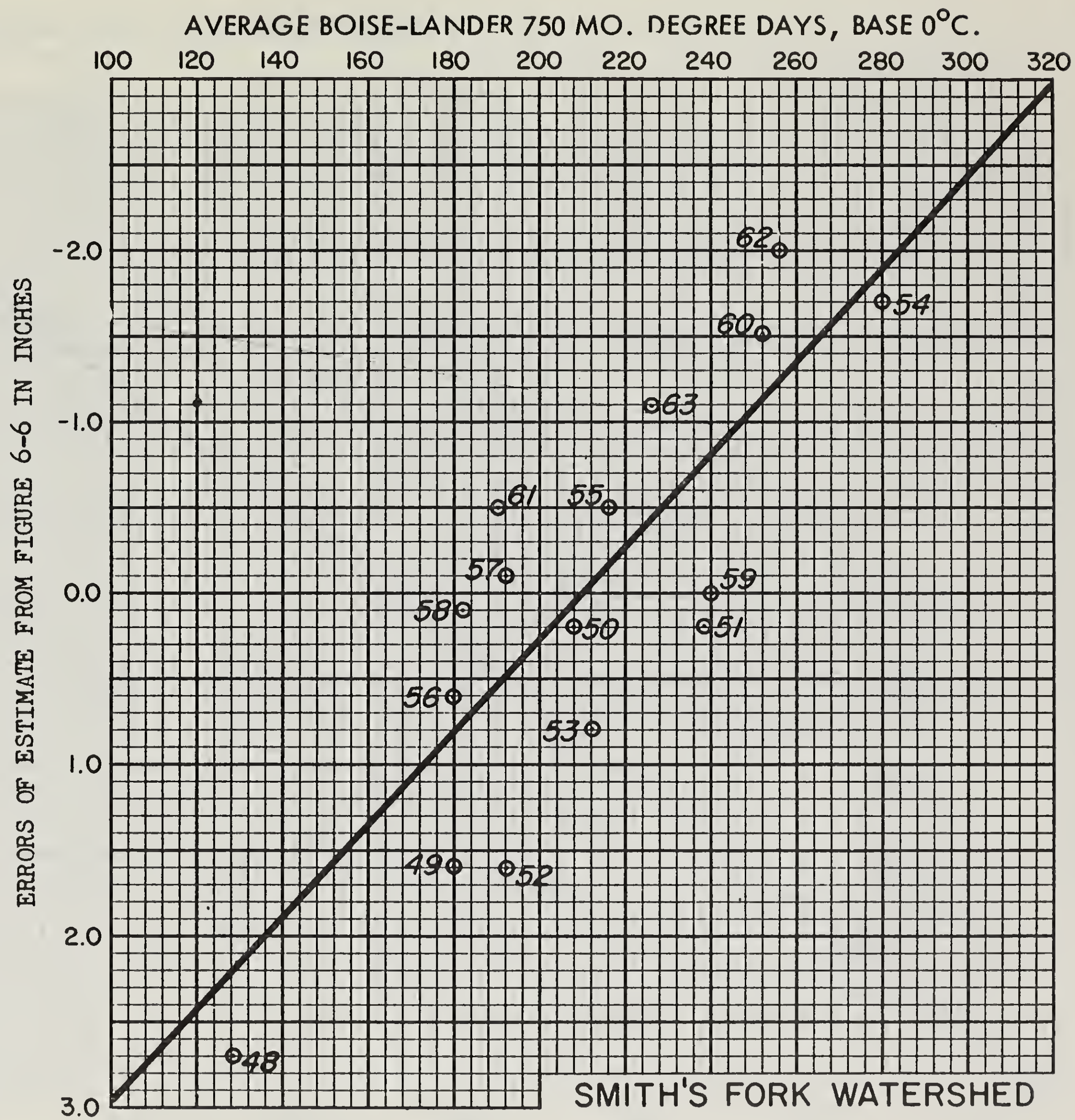

Figure 6-7.--Temperature index.

Year	Inches of Error Figure 6-7	Winter Sunshine Nov. April
1948	0.5	1250
1949	0.8	1202
1950	0.1	1238
1951	1.0	1140
1952	1.1	1222
1953	0.9	1253
1954	0.2	1335
1955	-0.3	1427
1956	-0.2	1382
1957	-0.6	1314
1958	-0.6	1318
1959	0.8	1263
1960	-0.4	1329
1961	-1.0	1446
1962	-0.8	1413
1963	-0.6	1438

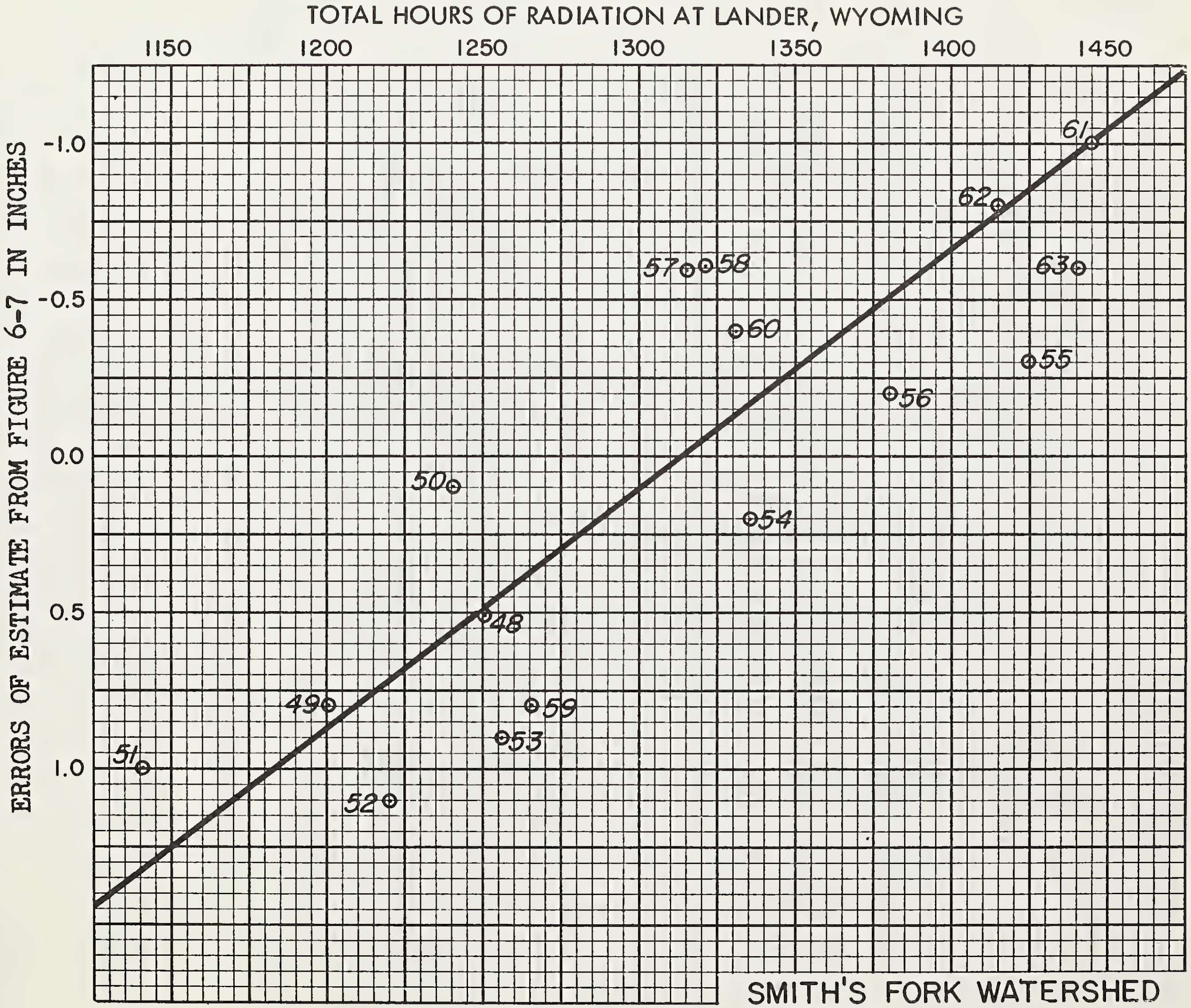

Figure 6-8.--Radiation index.

Year	Wind Index Curve Value	Temp. Index Curve Value	Rad. Index Curve Value	Total Water-Shed Loss	Errors of Est. Figure 6-5
1948	-4.9	2.2	0.5	-2.2	2.8
1949	-4.8	0.8	0.9	-3.1	1.8
1950	-5.6	0.0	0.6	-5.0	-0.3
1951	-6.8	0.8	1.3	-6.3	-1.6
1952	-6.7	0.5	0.7	-5.5	-0.1
1953	-1.9	-0.1	0.4	-1.6	3.9
1954	-6.8	-1.9	-0.2	-8.9	-3.4
1955	-3.0	-0.2	-0.9	-4.1	1.5
1956	-9.9	0.8	-0.5	-9.6	-4.3
1957	-1.1	0.5	0.0	-0.6	3.8
1958	-4.6	0.7	-0.1	-4.0	0.5
1959	-6.3	-0.8	0.4	-6.7	-1.3
1960	-3.5	-1.1	-0.1	-4.7	0.1
1961	-6.0	0.5	-1.0	-6.5	-1.4
1962	-6.0	-1.2	-0.8	-8.0	-3.0
1963	-2.2	-0.4	-1.0	-3.6	1.7

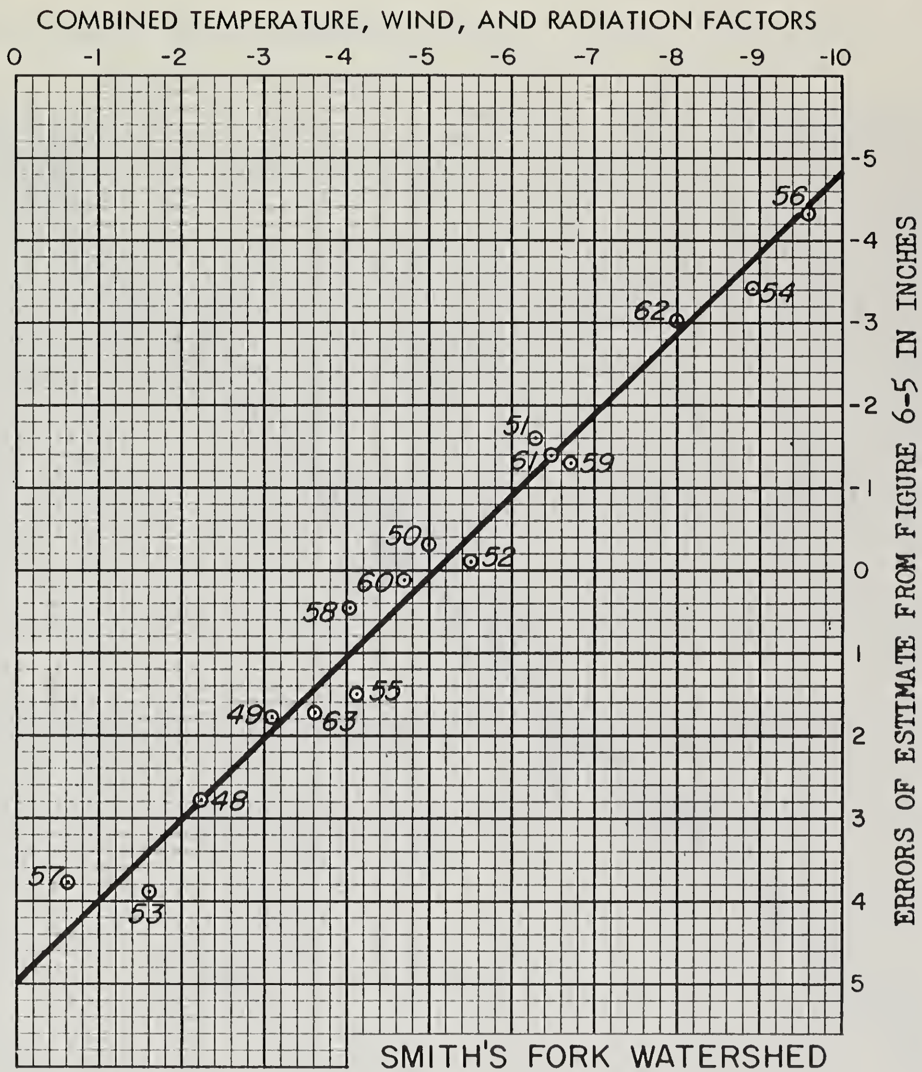

Figure 6-9.--Snowpack evaporation index.

Year	May 1 Water-shed Evap. Index	June 1 Usable Snow Course Index	June 1 Snow Pack Index	ASROM
1948	-2.2	20.3	18.1	111
1949	-3.1	20.0	16.9	102
1950	-5.0	29.5	24.5	153
1951	-6.3	30.2	23.9	149
1952	-5.5	25.4	19.9	126
1953	-1.6	17.4	15.8	99
1954	-8.9	23.3	14.4	89
1955	-4.1	16.5	12.4	78
1956	-9.6	33.4	23.8	152
1957	-0.6	24.7	24.1	148
1958	-4.0	22.8	18.8	112
1959	-6.7	19.8	13.1	80
1960	-4.7	19.0	14.3	83
1961	-6.5	15.5	9.0	49
1962	-8.0	30.7	22.7	142
1963	-3.6	19.0	15.4	95

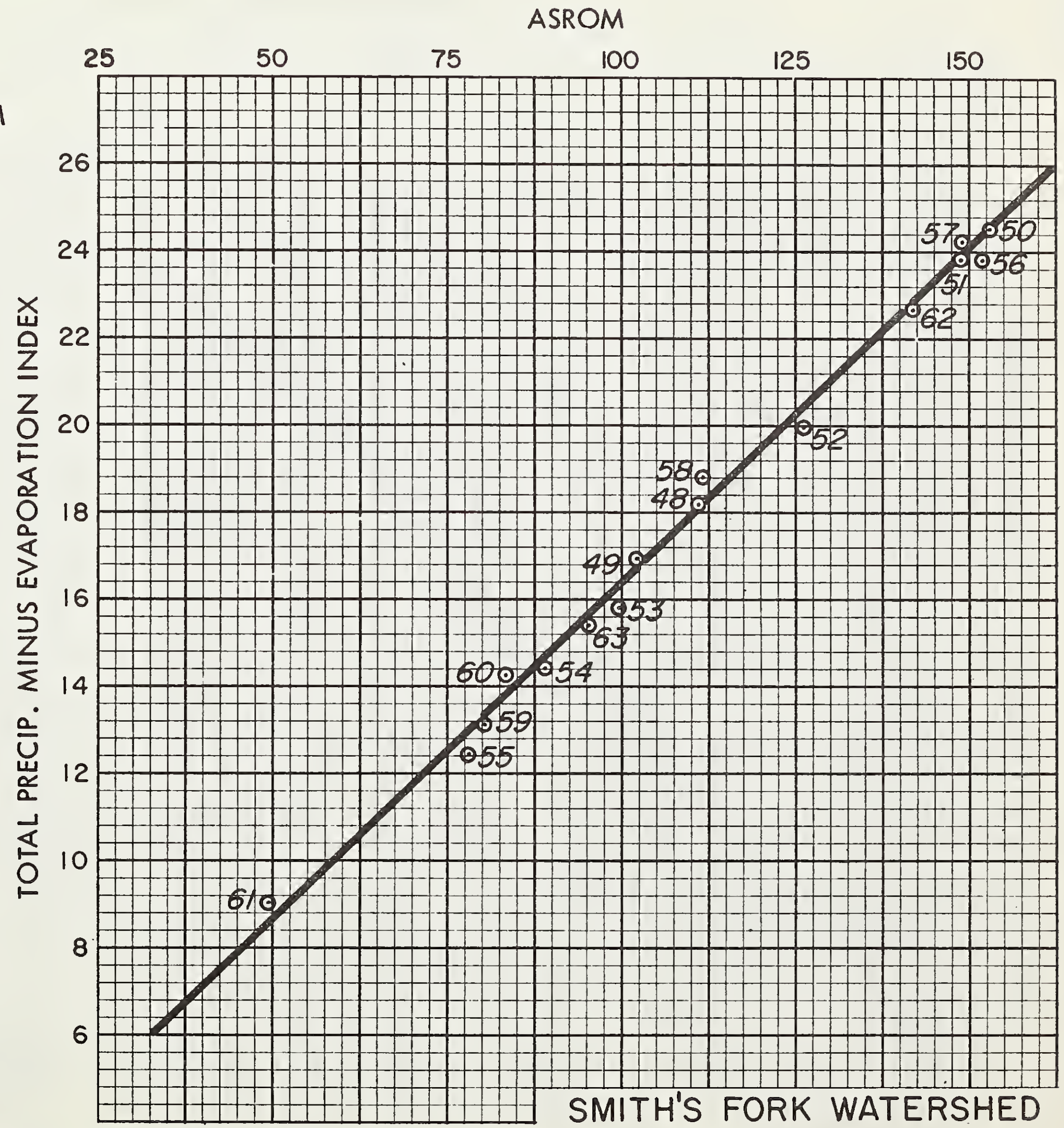

Figure 6-10.--June 1 watershed snowpack index versus April-September runoff (1000's acre-feet).

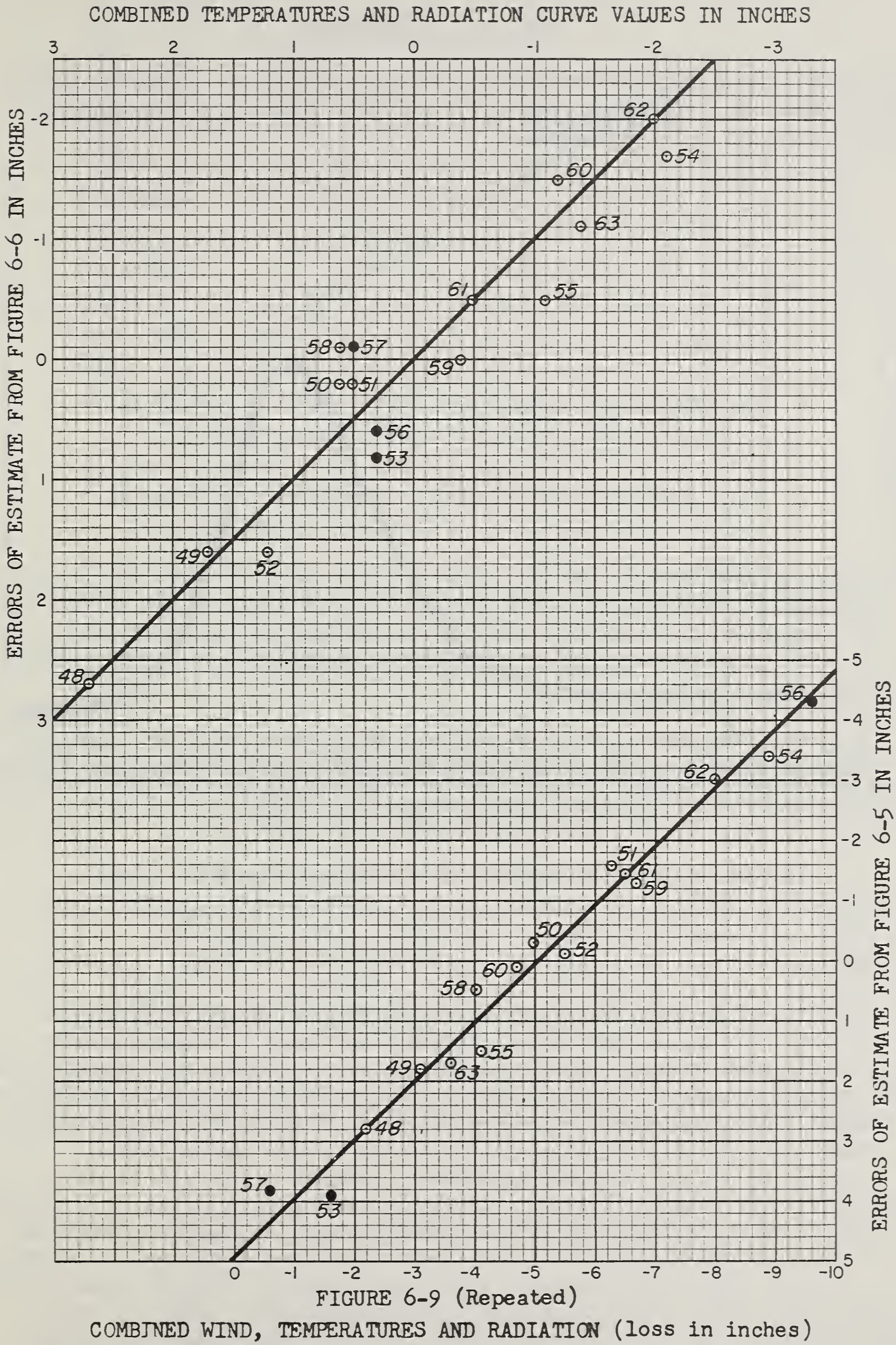

Figure 6-11.--Summary graphs.

Types of Forecasts

Forecasts issued by SCS are in four major categories: volume, peak or stage, residual, and hydrograph. Figure 6-12 shows a hydrograph of a typical western snowmelt stream.

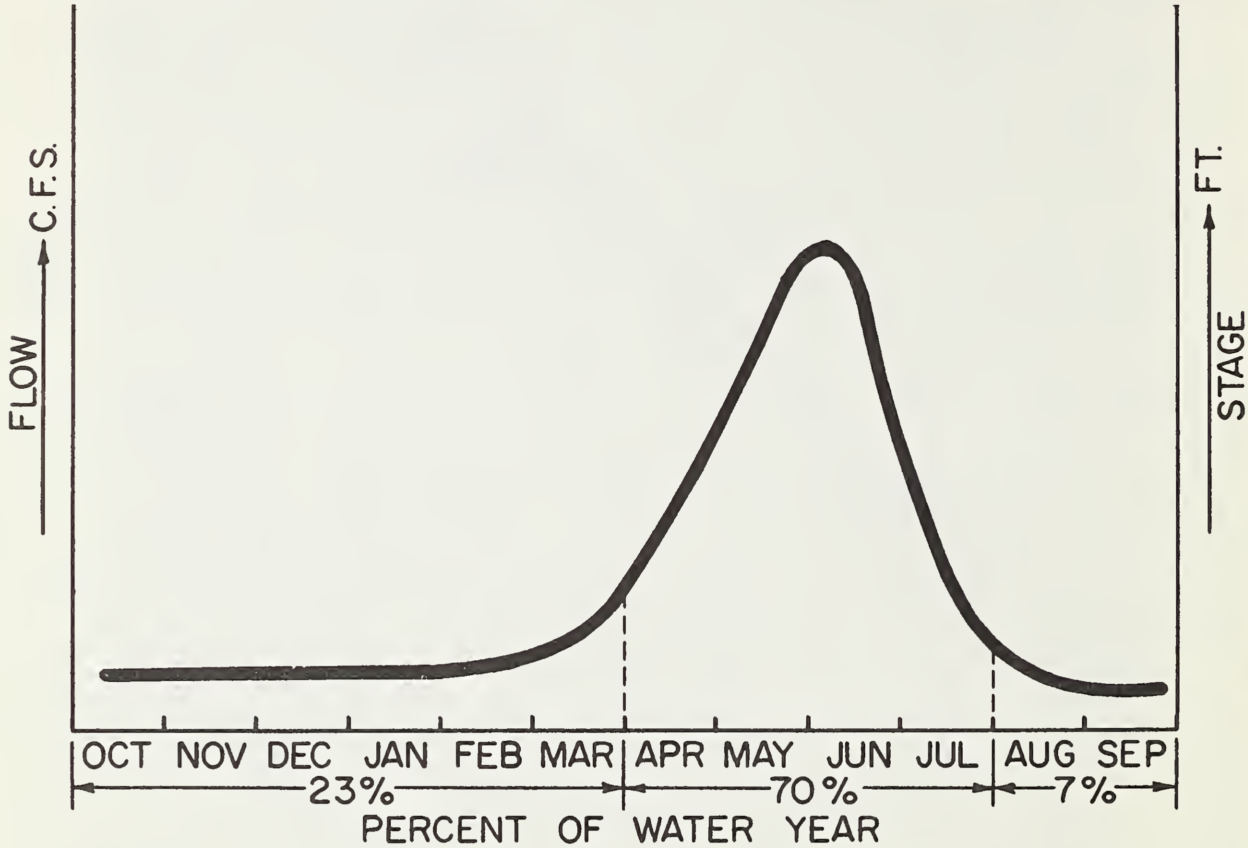

Figure 6-12.--Hydrograph of a western snowmelt stream.

Volume

Although there is some interest in and need for annual water-year streamflow forecasts, the major interest and need of western water users is for seasonal volume forecasts. Depending on geographic location and when snowmelt begins, the principal periods for most seasonal forecasts are April through July, March through June or July, and April through September.

Typically, the volume flow of a snowmelt stream from April through July represents 60 to 85 percent of its annual flow. On such a stream the correlation between snow water equivalent and April through July streamflow is high. The maximum snow water equivalent of Diamond Lake Snow Course (fig. 6-13) accounts for 73 percent ($0.852^2 = 0.73$) of the variability of the April through July flow of the Rogue River near Prospect, Oreg. This particular relationship can be improved by adding a fall precipitation index or soil moisture index and utilizing data

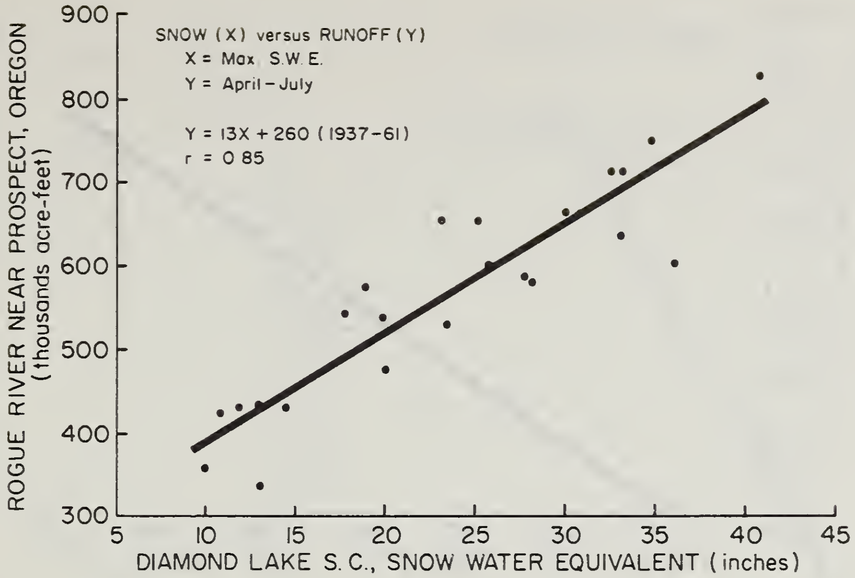

Figure 6-13.--Simple regression relationship.

from additional snow courses in the basin in the snow index. A spring precipitation index also improves the relationship. Since the actual spring precipitation data are not available at the time the April 1 and earlier forecasts are made, an average value has to be used.

Peak or Stage

A peak forecast predicts the maximum 1-day flow of water during the irrigation season or other periods. The quantity is usually expressed in cubic feet per second (cfs) or as the stage level in feet above a reference datum.

On a snowmelt stream the seasonal volume usually is closely correlated to the amount of the peak; the larger the volume, the higher the peak. Air temperature during the melt season is a major factor as is the precipitation. Figure 6-14 shows the relation between the peak flow and the April through June runoff of the Columbia River at The Dalles, Oreg.

Although predicting floods is a basic responsibility of other agencies, SCS coordinates its activities with these agencies to assist in providing this service to irrigation-water users in soil and water conservation districts. In addition, SCS prepares peak forecasts for some forecast points as an intermediate step in providing residual and hydrograph forecasts.

Residual

Water users are often interested in the number of days that streamflow will be above a specified amount or stage and the date on which the flow will fall below a specified flow level or stage. The procedure consists

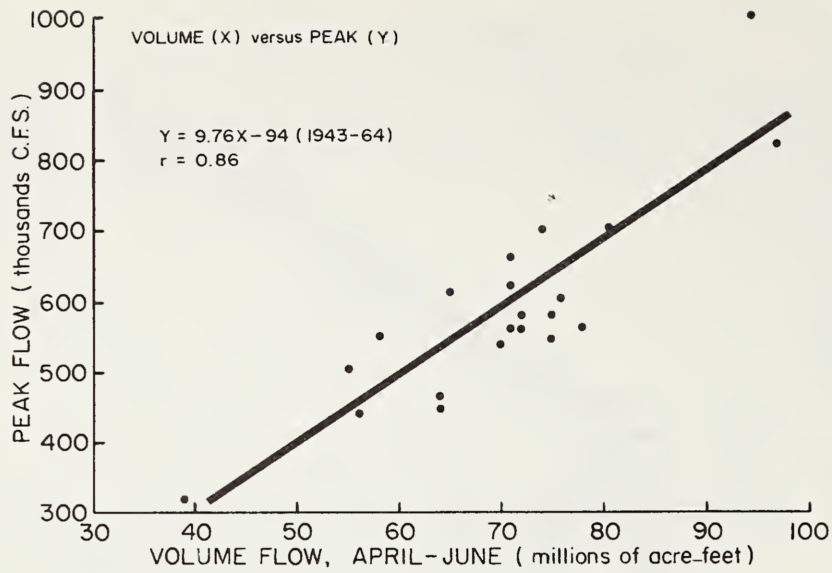

Figure 6-14.--Relationship between peak flow and seasonal volume--Columbia River at The Dalles.

of developing (1) a volume forecast relationship, (2) a volume-to-peak relationship, and (3) the relationship of peak to number of days above a specified flow amount. When the actual peak occurs, a forecaster can use a final relationship of the observed peak amount, date of peak, and the number of days until the peak falls below the specified amount.

Figure 6-15 illustrates this procedure in generalized graphic form. The entire procedure is usually prepared in algebraic equations, utilizing well-known statistical techniques.

Precipitation and temperature effects during the melt season are incorporated into the procedure by updating the volume forecast as data become available for spring precipitation and temperature.

Hydrograph

Hydrograph forecasts combine the three previously described forecasts. By combining the volume forecast, peak, date of peak, and predicted dates of specified flow amounts, a forecaster can construct a hydrograph. As runoff occurs, the hydrograph can be adjusted for observed data.

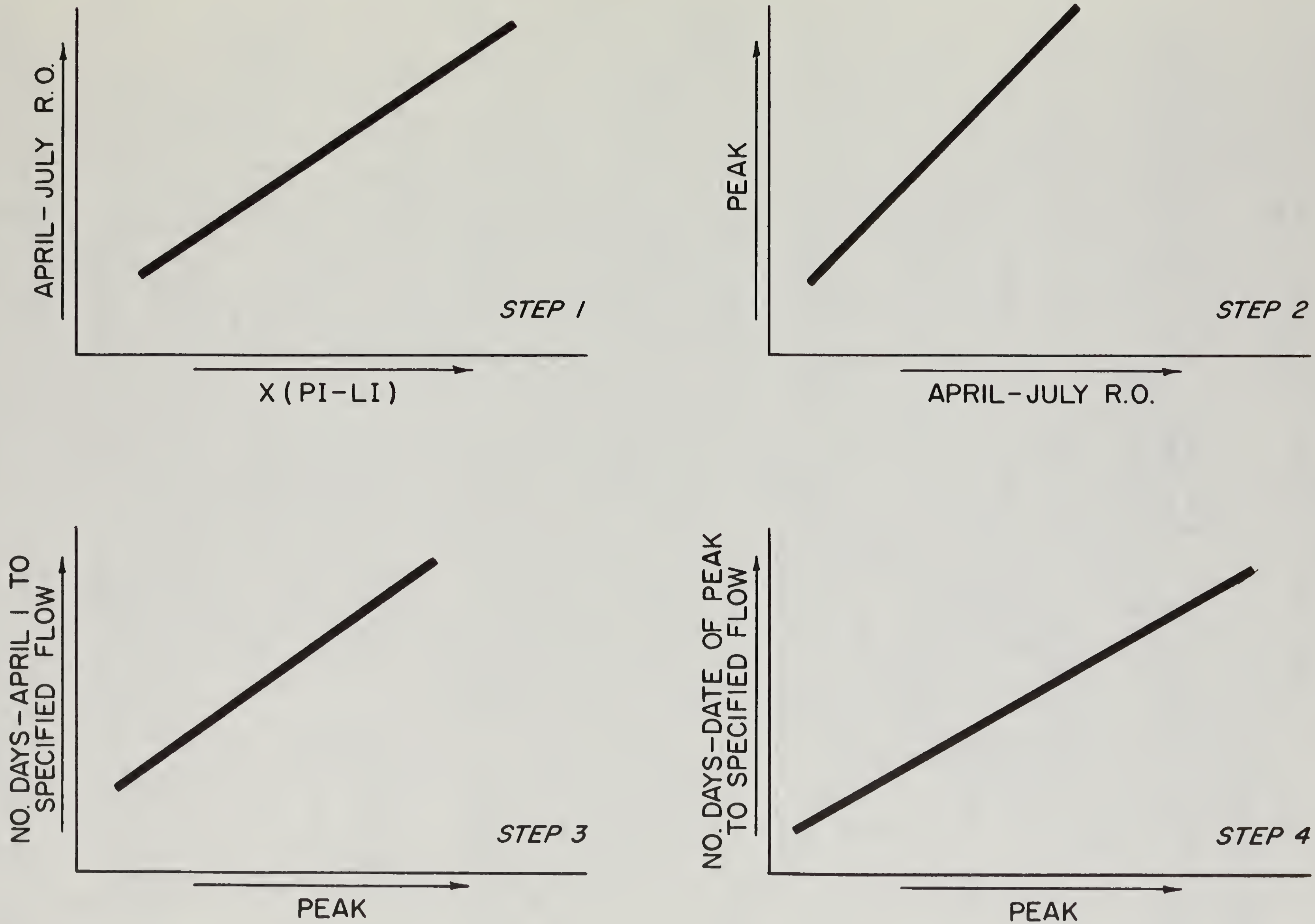

Figure 6-15.--Residual forecast procedure .

Development of Forecast Formula

General Use of Data

The procedure model for making water supply forecasts was discussed earlier in this chapter. Before proceeding to developmental techniques, the following basic assumptions regarding the data should be considered:

1. Climatic variations are small and unimportant with regard to the period of record. (Climatic variations are defined as large-scale world changes in climate.)
2. Future relationships between hydrological elements remain approximately the same as in the past.
3. Errors in observing and measuring related items (streamflow, snow survey, and precipitation data) are small and unimportant.

The first assumption is well established. Some authors have reported a gradual warming in the earth's climate. This warming has been over a longer period than the 20 to 30 years on which the majority of records used for runoff forecasting are based.

The second assumption is one that cannot always be validated. Sometimes the relationships between hydrologic elements do change. These changes can be thought of as second-order changes in the hydrologic cycle inasmuch as only the intensity of the relationship is affected. Such changes can be recognized and accounted for in the index method.

The third assumption that errors in observation are small and unimportant may be difficult to substantiate. But the limits of these errors can be fairly well established. One advantage in using climatic data for indexes is that the magnitude of errors in observation usually is much smaller than the magnitude of the element itself.

In preparing a forecast, the length of record to use must be decided. Often the decision is easy since there may be only one snow course or precipitation station and that station has a short record. One approach to this problem is to determine the correlation coefficient or regression coefficient between hydrologic elements, i.e., runoff and water content of a particular snow course, beginning with 5 years of record and then computing it successively for each additional year until the entire record has been used. In figure 6-16, it can be seen that, after Y years, the value of the correlation coefficient changes little from year to year. The number of years it takes for this situation to be reached can be taken as the <u>minimum</u> length of record that can be used with reasonable assurance that the relationship will remain fairly stable in the future.

Another characteristic of hydrologic data that influences determination of the length of record to use is the amount of variation in the element to be predicted, i.e., runoff. If the extremes of runoff vary greatly, a much longer record is needed for a stable mean since the addition of

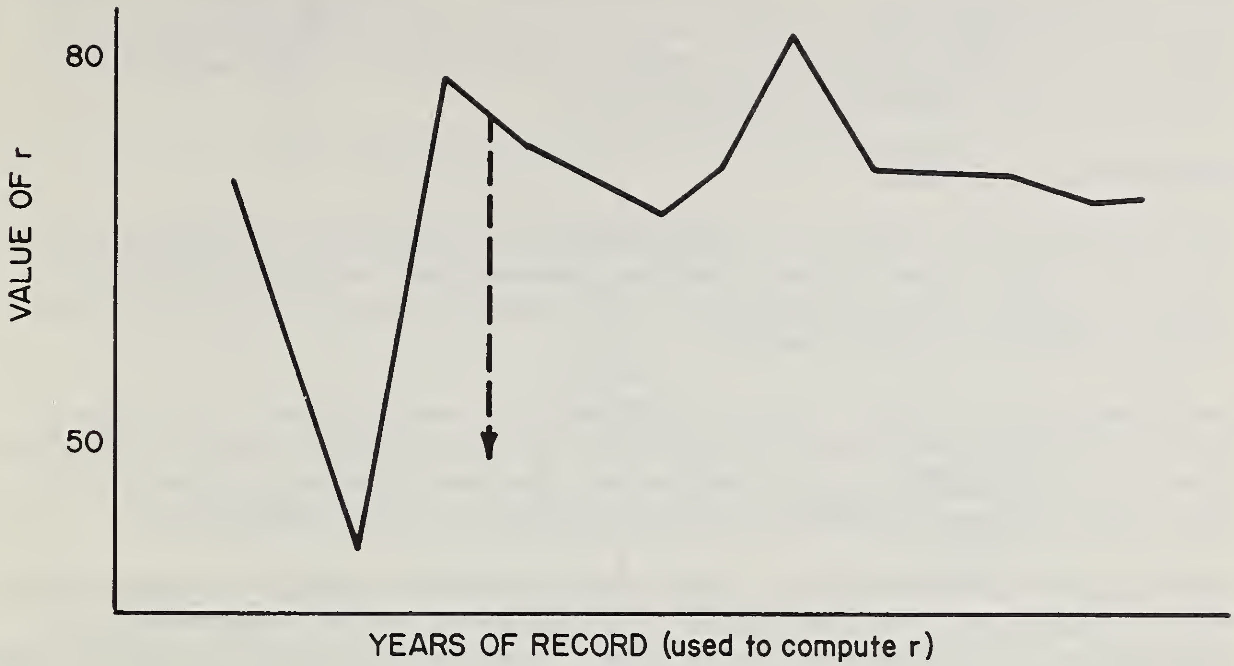

Figure 6-16.--Variability of correlation coefficient with time.

data for 1 year could change the mean a great amount. On the other hand, if runoff records have a small amount of variation, then the addition of 1 more year has only a small effect on changing the mean. Only by inspection and some analysis of the record is it possible to determine the length of record needed to insure an accurate operational forecast procedure.

The number of snow courses or stations needed to provide a useful index of runoff is another problem in forecasting. A single snow course often provides a useful index for basins of 200 to 400 square miles. But the basin area for which a single snow course can be used as a reliable index varies from locale to locale. In general, a basin that varies greatly in climatic regime and topography requires many snow courses to get a usable index. Basins that extend from very low elevations to higher elevations require snow courses at each elevation zone to represent dependably the basin snowpack each year. Conversely, a homogeneous basin may require only a small number.

Graphic Procedures

In the graphic method the independent and dependent variables are plotted on graph paper in such a manner that their relation to each other can be determined. If properly applied, this method gives very dependable results. But many of the statistical measures often needed in interpretation and in using this forecast procedure are extremely difficult to obtain. The best use for the graphic method is in preliminary work on forecast procedures and as a means of translating the complex mathematical relationships obtained by the statistical methods into more easily understand and usable graphic functions.

Detailing procedures for using the multitude of graphic methods available is beyond the scope of this section. Two books containing much information on this subject are: Applied Hydrology (1) and Methods of Correlation and Regression Analysis (2).

Statistical Procedures

In the statistical method the independent and dependent variables are related to each other by mathematical procedures. Various statistical measures useful in evaluating and interpreting forecast procedures are readily obtained by this method.

The procedures by which statistical measures are obtained are complex, yet at the same time the procedures can be standardized easily. For this reason, it is possible to determine and prepare forecast procedures by this method without completely understanding all the mathematics.

Detailing the procedures for using the statistical method is beyond the scope of this section. One paper and two books contain comprehensive information on this subject. They are: Statistical Control in Hydrologic Forecasting (3), Statistical Methods (4), and Statistical Theory in Research (5). Also see the Annual Proceedings of the Western Snow Conference (1948 through 1970) (6) and Derivation of Procedure for Forecasting Inflow to Hungry Horse Reservoir, Montana (7).

Use of Automatic Data Processing (ADP)

Development of forecast formulas and handling and retrieving other related data are ideally suited to ADP techniques. ADP can be defined as data input, processing, and output in a prescribed manner by a digital computer and its associated peripheral components controlled by a series of instructions called a program. Digital computers analyze extensive data rapidly at a moderate cost. Figure 6-17 shows a schematic diagram of an ADP application involving a multiple regression analysis, the principal technique used in developing forecast procedures.

Programs

Several programs that process data by using multiple regression analysis are available. They generally provide the following statistics: simple correlation coefficient (r), multiple correlation coefficient (R), regression coefficient (b), mean, "t" value, and standard error (SE).

All computer manufacturers provide extensive program libraries to ADP laboratories. As a result, it is not difficult to obtain appropriate programs that require only minor modification for the specific analysis desired. Many programs are written in special computer languages such as FORTRAN, COBOL, and ALGOL that will perform any mathematical, statistical, or logical operation. Such programs can be compiled on nearly every type of computer, and a program can be modified easily, especially in linking programs and changing requirements for data format. The latter is very important since it means that punched or magnetic-taped data can

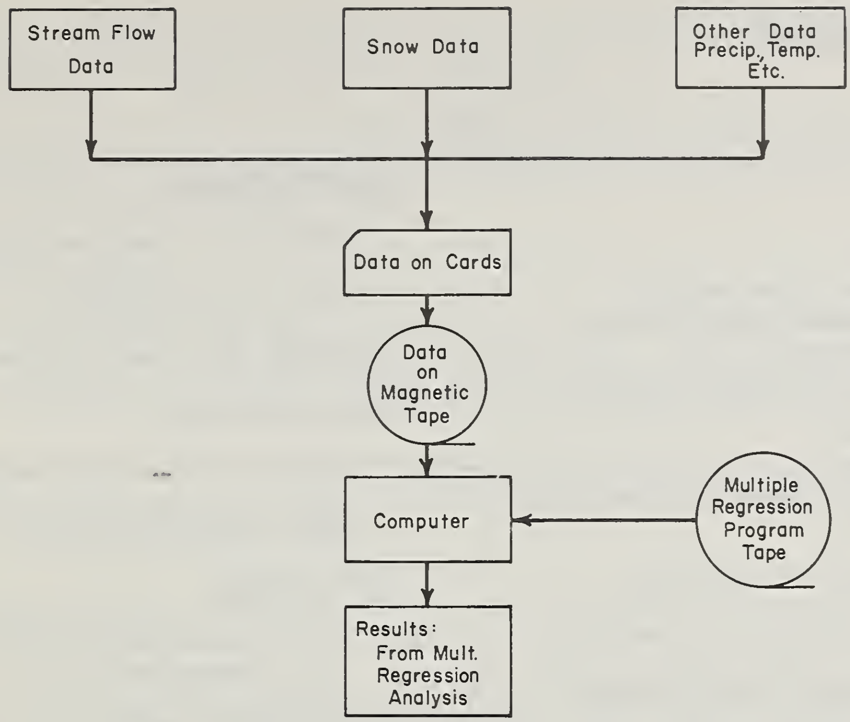

Figure 6-17.--Schematic: ADP technique.

be used and reused without repunching or reorganizing the data. Most ADP laboratories have numerous applicable programs written by their programers; these programs have been "debugged" and are available for immediate use. Figure 6-18 is a facsimile of a page from an IBM utility program manual, which gives some idea of the kinds of programs.

Data Input

The biggest problem faced by a forecaster in making maximum effective use of ADP is not programing or cost but data preparation. Input data must be organized in computer-readable form, which requires punching basic data either on cards or paper tape. If extensive computer analyses are contemplated, it is advisable to store most, if not all, basic snow, precipitation, streamflow, and other hydrologic data on magnetic tape. This master tape then can be used in many studies by computer retrieval of specified data.

The steps in getting data into machine-acceptable form are:

1. Prepare data listing using 80-column paper that meets program format requirements.
2. Keypunch data and verify.
3. Prepare a magnetic tape (optional).

In addition, identification and control cards are usually required. Often several analyses must be run before the final forecast procedure is

GUIDE TO SUBROUTINES

Figure 6-18.--Page from IBM program manual.

worked out. If a broad spectrum of data has been prepared for the initial run, it is not necessary to prepare new input data. Additional control cards that delete or manipulate are required.

A forecaster should have a good working knowledge of ADP. Two recommended references are Automatic Data Processing Systems (8) and the Fortran IBM Programmers Manual (9).

Errors in Forecasting

As in any field of science and technology, a water supply forecaster must use good judgment and scientific techniques. The phrase, "sound hydrologic judgment," applies specifically to water supply forecasting.

A certain amount of error is to be expected in forecasting, particularly the error associated with unexplained variation in a forecast equation known as the standard error (SE).

Two basic controllable kinds of errors are possible in forecasting. The first relates to errors in basic data for items such as incorrectly measured or computed snow survey readings, data mispunched on IBM cards, and erroneous posting of data on worksheets. This kind of error can be minimized by carefully double checking all basic data and proofreading IBM cards and listings. The second kind of error consists of mistakes in computation in developing forecast procedures and in preparing monthly forecasts. Extensive use of computers in developing forecast procedures has eliminated and will eliminate most of these errors if the basic input data are accurate.

When preparing forecasts, errors in computation can be avoided to some extent by preparing forecast worksheets well in advance of the report rush period. In this way the required averages, increments, and constants can be found without delay. If it is feasible, using graphs that represent previously determined equations reduces errors.

Often unsuitable data are detected while preparing a forecast procedure. These can be detected by double mass plottings, comparisons of the percentages of normal values, and probability plottings. If measurement methods were changed at some time and the record is long enough, one corrective measure is to drop the early record from the analysis. Use caution in dropping data on an individual-year basis such as dropping 1956 data from a 1948 to 1966 record. Such a procedure might be interpreted as deletion because the data do not fit rather than unsuitability due to error in the data. Another approach is to delete data for an entire station if it has a spotty record or an unfavorable location or if poor measurements have been taken.

Forecasts should be hydrologically reasonable. For example, in years of extremely low precipitation, forecast equations for certain Great Basin streams indicate less than no flow. Obviously, this is due to faulty fitting of the data in the forecast equation since flow cannot run upstream. In such instances the forecaster must adjust the forecast

upward to a reasonable minimum value. Similarly in a year of heavy snow the forecast may indicate greater flow than any previously observed. The forecaster may have to adjust the forecast downward to the largest previously observed amount. The essential fact to remember is that forecasts well above or below observed upper and lower limits used in preparing a forecast equation may be subject to large errors.

An effective method for controlling unwarranted errors in individual forecasts and for insuring reasonable hydrologic results is to compare forecasts expressed as percentage of average or in terms of probability to those for adjacent streams. As a general rule, the percentages for adjacent streams or streams with common headwater divides should be reasonably equivalent.

Thus, a forecaster tends to be suspicious of a forecast for a stream that exceeds forecast outlook for neighboring streams by 20 percent or more if the record shows 15 percent to be the maximum difference. Comparisons should be prepared for a representative historical period to have the appropriate maximum percentage or probability difference limits for associated adjacent streams.

In developing forecast procedures, the forecaster must determine whether the known data (including such items as spring precipitation) are adequate compared with unknown or unmeasured data. That is to say, "Is the forecast more accurate than would be obtained by forecasting an average flow each year?" Obviously, if it is not, additional data must be obtained and, until they are available, a forecast is not warranted.

Scheduling of Forecasts

Seasonal water supply forecasts should be issued well in advance of the season. Thus, a forecast for April through July issued on March 1 is often more valuable to water users for planning than a forecast issued on April 1 for the same period, if the March 1 forecast is accurate.

In many areas, water users cannot make crop adjustments, obtain seed or additional equipment, spill or store water, and buy supplemental water if the forecast is issued too late in the season or is delayed. Timeliness and accuracy are essential to forecasting.

Often the pattern is well established by mid-January in winters that are extremely above or below average. Thus, in such years a forecast issued as early as February 1 usually will hold up well because in many areas of the West 40 to 50 percent of a normal winter's snowpack is on the ground by January 1. Accordingly, if snow surveys on January 1 indicate that 80 to 100 percent of the normal maximum snow water equivalent for the year is already in the mountains, there is little, if any, likelihood that snowmelt runoff will be less than average. The converse is also true, but it is necessary to wait until late February or early March before a firm prediction of subnormal runoff can be issued.

Preliminary forecasts, those issued before April 1, are generally less accurate than those issued on April 1 or later. The reason is that most

of the indexes have to be projected to their date of maximum amount or estimated for indexes such as spring precipitation (usually average values are used). The forecaster should analyze the accuracy of each forecast procedure according to the percentage of data that is known and the percentage that is estimated for each forecast index for each forecast date.

The following statistics pertain to the accuracy of SCS Westwide forecasts (1922-1963) computed by the percentage difference method; 1963 is not complete, however.

	Number of forecasts	Percentage of accuracy
Date forecast issued:		
Feb. 1	1,593	21.6
Mar. 1	3,980	20.0
Apr. 1	6,515	18.6
May 1	4,928	15.6

Errors in forecasting are costly. Water users spend large sums of money in their water-based activities. Every effort must be made to reduce errors to a minimum, particularly those that can be controlled.

Forecast Accuracy

Purpose

The primary objective of the snow survey and water supply forecasting activity is to provide timely and accurate seasonal streamflow forecasts. Forecast accuracy values provide a confidence index when issuing forecasts or making water management recommendations; a basis for determining which forecast equations need improvement; and a basis for comparing alternative forecast procedures, forecasters, and state and basin differences.

Procedure

There are several ways to calculate forecast accuracy. SCS used a percentage-error method before 1963. The equation is:

$$\text{Percentage error} = 100\,\frac{(\text{forecast flow - observed flow})}{\text{observed flow}}$$

Each numerical percentage error was given an error classification ranking.

Percent	Ranking	
0 - 5..................	Excellent	(1)
5.1 - 10..................	Good	(2)
10.1 - 20..................	Fair	(3)
20.1 - over..............	Poor	(4)

A percentage-difference method for expressing forecast accuracy is recommended. The equation is:

$$\text{Percentage error} = 100 \frac{(\text{forecast flow})}{(\text{average flow})} - 100 \frac{(\text{observed flow})}{(\text{average flow})}$$

or

$$= \frac{100}{\text{average flow}} (\text{forecast flow} - \text{observed flow})$$

The average flow value is the 15-year average in use at the time the forecast is issued. If the forecast flow is less than observed flow, the percentage of error is posed with a minus sign. The percentage of error for a forecast in excess of the observed flow is posted without a sign although a plus sign can be used if desired. An example of the computation follows:

Forecast flow = 85 (thousand) acre-feet
Observed flow = 95 (thousand) acre-feet
Average flow = 75 (thousand) acre-feet

$$\text{Percentage error} = \frac{100}{75} (85 - 95) = \frac{4}{3} (-10) = -13.3 \text{ percent}$$

No changes are made in error classification ranking. Thus, in the example above, the -13.3 percentage of error is "fair" (3).

Reporting

A standard form is recommended. SCS forecast accuracy form (fig. 6-19) meets most needs. This form is designed for either manual or automatic data processing methods. One sheet or more, depending on length or record, is used for each station (forecast point) and forecast period. Thus, if a given station has two forecast periods, April through July and May through July, at least two sheets are required.

If forecast accuracy is determined manually (longhand, slide-rule, or desk calculator), it is not necessary to fill out the code line (upper left top).

WSFU has a computer program that uses the data on the left half and top of the accuracy form to compute the forecast accuracy. The data coded on the input and output cards, the procedure for obtaining such data, and the coding system follow:

Input card

Data	Procedure
State River basin River subbasin River station Forecast period Basin size	Prepared from codes.
Year	Taken from accuracy form.

WSF-1 (Revised 9/2/58)

UNITED STATES DEPARTMENT OF AGRICULTURE
SCS FORECAST ACCURACY OF WATER SUPPLY FORECASTS

Sheet # 1 of ____
State Washington
Basin Upper Columbia
Drng. Area 1000 Sq.Mi.

Code 10-14-08-01-02-04
River Station Wenatchee at Peshastin, Wn.

Forecast Period April-July

Runoff Thousands Acre-Feet

	Forecast				Observed		
Year	Feb. 1	Mar. 1	Apr. 1	May 1	Flow	Average	
1961		1620.0	1623.0		1770.0	1704.0	
1962		1558.0	1195.0		1324.0	1704.0	
1963		1070.0	1040.0		1050.0	1704.0	
1964		1790.0	1825.0		1735.0	1704.0	
1965		1740.0	1710.0		1604.0	1758.0	

CODE 10 - State - Washington
" 14 - Basin - Upper Columbia
" 08 - Sub-Basin - Wenatchee
" 01 - Station on Stream - Peshastin
" 02 - Forecast Period - April-July
" 04 - Basin Size - 701 - 1000 square miles
66 - Year - 1966
401 - Forecast Date - April 1

- - - - - - - C O R R E C T I O N S * - - - - - - -

	Forecast				Observed		
Year	Feb. 1	Mar. 1	Apr. 1	May 1	Flow	Average	
1961		1620.0	1623.0		1777.0	1704.0	

* When making corrections please use lower portion of form, listing complete corrected data, but do not obliterate the original data.

REMARKS:

Figure 6-19.--SCS forecast accuracy form.

Input card--Continued

Data	Procedure
Forecast date	Taken from accuracy form.
Forecast Observed flow	Taken from accuracy form.
Average	Taken from accuracy form.

Output card

State
River basin
River subbasin
River station
Forecast period
Basin size
Year
Forecast date
 (Error class)
  Excellent
  Good
  Fair
  Poor
Number of forecasts
Plus
Minus
Percentage of error

Codes

State
01 Arizona
02 California
03 Colorado
04 Idaho
05 Montana
06 Nevada
07 New Mexico
08 Oregon
09 Utah
10 Washington
11 Wyoming
12 North Dakota
13 South Dakota

River basin
06 Upper Missouri
07 Arkansas

River basin--Continued
08 Rio Grande
09 Colorado
10 Great Basin
11 California and Pacific Coastal
12 Lower Columbia
13 Snake
14 Upper Columbia
15 North Pacific Coastal
16 North and South Platte

River subbasin
Available from WSFU on request.

River station
Available from WSFU on request

Codes--Continued

Forecast period
01 April-September
02 April-July
03 April-June
04 July-September
05 March-July
06 May-September
07 May-June
08 February-April
09 March-April
10 March-May
11 April-May
12 February-May
13 March-June
14 January-May
15 March-September
16 January-June
17 February-June

Forecast period--Continued
18 June-September
19 April-August
20 May-July
21 May-August
22 February-September
23 February-July

30 Stream year
31 Peak storage
32 Maximum rise in tenths of feet from April 1 assuming gates closed
33 Maximum rise in tenths of feet from May 1 assuming gates closed

Basin size (sq. miles)
01 0-100
02 101-400
03 401-700
04 701-1,000
05 1,001-3,000
06 3,001-5,000

Basin size (sq. miles)--Continued
07 5,001-10,000
08 10,001-15,000
09 15,001-25,000
10 25,001-100,000
11 100,001 and over

Forecast date
101 January 1
115 January 15
201 February 1
215 February 15
301 March 1
315 March 15
401 April 1

Forecast date--Continued
415 April 15
501 May 1
515 May 15
601 June 1
615 June 15
701 July 1
715 July 15

Currently, data-input decks, data-output decks, and listings (complete through 1962) are available from the unit. The output cards and listings give the percentage of error, sign, and error classification. These results can be manually transferred to the standard form. These decks are adapted by the unit, and the results are furnished to supervisors for the state or states under their jurisdiction.

Interpretation of Results

Forecast accuracy data provide a forecaster with three kinds of information that can be used to evaluate forecasts--percentage of error values, sign designation, and error classification rankings. Each is discussed in the following paragraphs.

Percentage of Error Values

Compare stations with high individual percentage of errors and mean (average) percentage of errors to the percentage error that would have resulted if average flow had been forecast in lieu of the forecast issued. If the mean percentage of error using the average each time as the forecast value does not exceed the mean percentage of error using the forecast procedure by at least 1.5:1, the forecast equation and procedure should be reviewed. For instance, if the average forecast error is 20 percent and the mean deviation of flows from average is 25 percent, the forecast procedure needs reevaluation.

Forecast accuracy should improve as the season passes. For example, the mean percentage of error of an April through July forecast for a station or group of stations made on April 1 should be less than the mean percentage error of a forecast made on March 1 for the same period and station or group of stations.

If seasonal streamflow at a station or group of stations is extremely variable, then the percentages of error can be expected to be larger than that for a station with moderate streamflow variability.

Sign Designation

As a general rule, there should be about an equal number of plus and minus forecast percentages of error at a forecast point or group of stations. If there is a significant variation from this 1:1 ratio, the forecaster should first review the published forecasts to determine whether this was caused by adjusting the forecasts derived from the forecast equations. If so, the forecaster should reevaluate his adjustment procedures. Factors to look for are skewed data, inappropriate or imperfect transformations, use of linear relationships when curvilinear relationships are applicable, and vice versa.

Error Classification Rankings

Rankings of error classifications provide a rapid method for evaluating forecast accuracy, but they are somewhat arbitrary or subjective in that they do not take into account differences between stations. Consider the following streams:

C-1	C-2	GB
Columbia Basin stream April-July--no diversion above forecast point. Mean percentage of error = 8.5 percent.	Columbia Basin stream April-July--no diversion above forecast point. Mean percentage of error = 11.1 percent.	Great Basin stream April-July--diversions for irrigation above forecast point. Mean percentage of error = 20.5 percent.

Error Classification Rankings	Streams C-1	C-2	GB
Excellent	10	5	1
Good	5	8	2
Fair	3	4	7
Poor	2	3	10

It is obvious that stream GB cannot be compared directly with stream C-1 or stream C-2 on error classification rankings alone. The comparison between stream C-1 and stream C-2 with very similar conditions would indicate to the forecaster that the procedure for stream C-2 should be reviewed.

Records

Records of forecast accuracy should be kept for all forecast stations and time periods. Periodic updating and review of records are recommended (see SCS ENG-MEMO-59, Snow Surveys and Water Supply Forecasting, dated September 7, 1967).

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4. Snedecor, G. W. 1966. Statistical Methods. Iowa State University Press, Iowa. 534 p.

5. Anderson, R. L. and T. A. Bancroft, 1952. Statistical Theory in Research. McGraw-Hill Book Co., Inc., New York. 399 p.

6. Soil Conservation Service. Annual Proceedings of the Western Snow Conference. 1948-70. Papers relating to statistical procedures and their application to specific streamflow forecasting.

7. Water Management Subcommittee. Columbia Basin Inter-Agency Committee. 1964. Derivation of Procedure for Forecasting Inflow to Hungry Horse Reservoir, Montana. 63 p.

8. Gregory, R. H. and R. L. Van Horn. 1960. Automatic Data Processing Systems. Wadsworth Publishing Co., Inc., San Francisco, Calif. 705 p.

9. Fortran IBM Programmers Manual. Updated versions are published currently and are available from IBM Corporation.

CHAPTER 7. REPORTING

CONTENTS

CHAPTER 7. REPORTING

Purposes

Data releases and water supply outlook reports serve three broad purposes. They (1) provide basic data gathered by SCS to users on a schedule that meets their needs; (2) provide a formal and concise record of the data gathered along with other data affecting water supply; and (3) report to the public the data and water supply outlook in graphic, tabular, and narrative form.

Preparation of news releases, formal state and westwide water supply outlook reports, and other data requires detailed knowledge of water needs and use practices in the forecast area and professional interpretations of the impact of water supply outlook conditions.

Release of Data

In general, the data are gathered and the information is reported on a monthly basis from January 1 through June 1. Special reports may be issued on other dates. With the development of automatic data sensing and transmitting equipment and the increasing demands for data that affect the control and use of water, more frequent reporting will undoubtedly be needed in the future. Formal reports are available to water users 10 to 15 days after the basic data are collected. Some users, however, need basic data as soon after the collection date as possible.

By Local Personnel

Snow surveyors and work unit personnel should provide basic data to local water-using organizations and the local news media as soon as they are obtained. Normally, this is done through news stories. The data for the current year should be reported and compared with data for the same date in the preceding year and with the average for that date. Other information, such as the minimum or maximum reading for that date, may be supplied if the current data are among the extremes of past record. Credit should be given to other agencies making snow surveys in the general area.

By State Offices

State offices provide advance data to all interested cooperators who request such information. If the requests are few, data can be supplied by telephone or letter. If more than 10 cooperators desire the information, it should be tabulated by snow course, date of measurement, snow depth, water equivalent, and possibly the past average, and then typed and duplicated. The data should be released as soon as 90 percent of the state data are available and have been checked for accuracy, usually 3 days after the date of measurement.

By Water Supply Forecasting Unit

The SCS Water Supply Forecasting Unit (WSFU) coordinates the distribution of data to water users who need information that goes beyond state boundaries. A water user's name can be added to state or WSFU distribution lists. WSFU also needs advance data for redistributing and preparing reports.

Release of News to Mass Media

Information on water supply outlook should be provided to news outlets after each snow survey date.

The snow survey supervisor is responsible for news releases on water supply forecasts at local and state levels. Westwide releases are the responsibility of WSFU.

Kinds

Local

SCS area and work unit offices responsible for making snow surveys should write news stories suited to local conditions for local news media immediately after the completion of each field snow survey. The stories should include information about organizations participating in snow surveys and about snow conditions, water content, and other items noted on a snow survey trip. They may also include information on local precipitation or reservoir storage. News releases that include streamflow forecasts or statements of impact on water supply conditions should not be made locally without clearance from the state office; this clearance usually can be obtained by telephone.

Opportunities to appear on radio and television should be used. Local radio and TV stations generally are pleased to present snow survey information on news programs and interview shows, either "live" or on videotape. Water supply outlook often can be combined with information on other SCS activities.

State

Statewide news releases (300 to 500 words) are prepared by the snow survey supervisor and follow the usual news article format with general water supply conditions stated in the first few sentences and details in later paragraphs. The purpose of these releases is to present a broad picture of a state's water supply outlook. In contrast to local releases, actual data usually are not listed. Factors relating to water supply outlook, such as snow cover, precipitation, reservoir storage, soil moisture conditions, and streamflow forecasts, are reported as percentages of the average or are compared with those of the previous year. During extreme years, these factors may be compared with previous records to emphasize a shortage or high-water conditions.

Sometimes state offices also prepare news stories for local release.

Regional

Regional news releases are prepared by WSFU from information received from states. Because of the area covered, information is general, stated in broad terms and emphasizes unusual water outlook conditions. Data reported are limited to those showing relation to the average, the previous year, maximum or minimum.

WSFU prepares special articles on water or related fields for magazines or publications that have regional or larger circulation.

Special

Special news stories and press releases are prepared by the snow survey supervisor. Unusual drought or excessive water conditions, improvements in techniques, special use of data, and similar items may provide the basis for interesting and timely news stories.

Water Supply Forecast Meetings

Basinwide meetings are planned and sponsored jointly by WSFU and a cooperating agency or group of water users. These meetings provide a good opportunity for a news release covering an entire basin or a large stream. Local water supply forecast meetings are planned by the state snow survey supervisor. Usually one or more soil and water conservation districts sponsor such a meeting and invite watermasters, irrigation district managers and directors, representatives of local farmer organizations, soil conservation districts, industry, domestic water supply and power companies, banking and loan institutions, federal and state agencies concerned with water management or problems of water management, and key farmers and ranchers. Representatives of newspapers, radio, and TV are invited. Such meetings may last a half day but usually can be completed within 2 hours.

Contact with Editors

It is a good idea to make a personal visit to the editor well in advance of the planned release time of a news story. The editor can then expect the item and arrange space for it. Some editors may follow up from time to time to pick up new leads. Advance contact should be made with:

Associated Press
United Press International
Daily and weekly newspapers
Key radio and TV stations

Try to personally visit the editor to deliver your written news release or telephone him. Let him know that the release is "canned" if it is going to several editors or that it is only for him. For newspapers and radio, and TV stations outside the urban area, mail the release to all sources at the same time. Special timing may be required in providing releases for use in weekly papers.

Sometimes the snow survey supervisor finds it best to mail or phone the news release to the district conservationists in the communities that have newspapers and radio stations and count on them to sell the story to the editors.

Writing

News writing should combine clarity and directness with easily understood words in short sentences. Be sure to put the single, most important piece of news in the first short sentence. Follow up the WHAT with WHO, WHERE, WHEN, WHY, and sometimes the HOW!

If you are giving your news release to only one editor, provide him with the original copy and tell him it is an "exclusive." If you are distributing a news release to all outlets, the editor should be able to see at a glance that he has a copy rather than an original. And always file a copy of the release in your office. The Information Units of SCS can assist in the techniques of preparing news releases. A news release has:

1. Space at the top of the sheet for the editor to write in a news headline.
2. The date and the words "For immediate release" in the upper left hand corner.
3. The entire narrative typed double-space.
4. At least two line spaces between paragraphs.
5. The word, "MORE," at the bottom of the first sheet if another sheet is needed.
6. The second sheet marked "Page 2" in the upper right-hand corner.
7. The word, "END," at the end of the news statement.
8. The name and address of the issuing office in the lower left-hand corner together with the telephone number of the writer of the release. Then the editor can contact the writer directly for further information if needed.
9. A "credit line" that includes the names of the state conservationist, the writer, and possibly one or two principal cooperators. (The editor will very likely take out the reference to the principal cooperators unless they are quoted. An editor needs only one name to refer to if some reader criticizes the reporting of the water supply conditions.)

State Water Supply Outlook Report

State reports are the basic reports of water supply outlook and cooperative snow surveys. These reports contain data gathered by SCS and its cooperators, summaries of other data affecting water supply outlook, forecasts of streamflow, and a narrative describing water supply conditions and their impact on water use for the subwatersheds in the state.

Format

A standard format should be followed by all states. The time and reproduction facilities available may make it necessary to use a special format and procedure, but such use should be the exception. The following paragraphs prescribe features of the report that are to be alike in all states.

Covers and Title Pages
The format of covers and title pages used on all regular state and regional reports is prescribed by WSFU annually.

The front cover shows "Prepared by U.S. DEPARTMENT OF AGRICULTURE - SOIL CONSERVATION SERVICE," the title "WATER SUPPLY OUTLOOK FOR (STATE)," and the date of the report. "FEDERAL-STATE-PRIVATE COOPERATIVE SNOW SURVEYS" is shown in the upper left-hand corner in bold type but smaller than the title. One or two major cooperators may be shown in large type if arrangements so require. Minor cooperators are listed in small type at the bottom of the page, or reference is made to where they are listed.

The material for the inside front cover is prepared by WSFU. It contains a brief narrative statement on snow surveys, the state and major reports available, and the addresses where the reports can be obtained. The inside back cover may list the cooperators in the program or be left blank. The back cover is designed for use as a postage-free mailing sheet.

To assist in identifying various state reports, WSFU has selected covers of different colors for each state. The Portland Cartographic Unit follows this designation when preparing the covers.

The title page names the SCS Administrator and states that the report was released by the state conservationist. Heads of the major cooperating agencies may also be listed, if required. The principal title of the report is "WATER SUPPLY OUTLOOK FOR (STATE)." Credit to those who prepare the report is shown at the bottom of the sheet.

Data Station Index Sheet
At least once each year a map of the state or area maps is included with the water supply outlook report and shows the location of active snow courses, soil moisture stations, air markers, precipitation stations, or other data sites that are a part of snow surveys. If needed for understanding of forecast information, maps should be included in each report.

Narrative, Tabular, and Graphic Information
Because of differences in printing and reproduction facilities used by state offices, the format of data and narrative pages of the water supply outlook report varies.

Narrative.--The narrative section of the water supply outlook report should emphasize the impact of the outlook on water use. Water supply outlook considers not only the streamflow forecast but also the total water available, including storage and the demands for use in relation to prospective supply. Repetition of data is avoided except for summaries of conditions.

Data on present streamflow or flow for the water year to date are not required in water supply outlook reports. Where they are significant, the information should be covered in narrative statements. If data are shown, a graphic presentation of water-year-flow-to-date compared to average, minimum, and maximum of record for the snow course average period is preferred.

A map showing streamflow prospects or water supply outlook conditions in broad terms is desirable. If streamflow prospects are reported, overlay codes on the state map should represent conditions such as "much above average," "above average," "near average," "below average," and "much below average." As a guide, these terms might represent values such as more than 130 percent, 110 to 130 percent, 90 to 110 percent, 70 to 90 percent, and less than 70 percent, respectively, and should be defined in the report. On streams where seasonal flow varies over a narrow range, these percentage ranges may also be narrowed. If it is common for seasonal streamflow to be more than 130 percent of average or less than 70 percent of average, these percentage ranges should be expanded. If the map shows general water supply outlook, terms such as "adequate," "limited shortage," and "severe shortage" are appropriate.

Snow Data Tables.--The tables should show snow survey data gathered for current water supply outlook report. Midmonth surveys, special surveys, and snow pillow data may be included in special reports, in monthly reports, or combined in the last report of the snow season.

The tables show, as a minimum, the name of the snow course, date of measurement, snow depth in inches, and snow water equivalent in inches and tenths for present data. On the same line, the snow water equivalent for the past average is listed. Data for the same date for the previous year may also be listed.

The period used as an average prescribed by WSFU is based on agreement with other agencies in the water field. The present practice is to use a relatively recent period of record--15 to 20 years--and to update the period of record every 5 years. If space is available, the code number and elevation of the snow course are shown. The snow courses are listed alphabetically by major drainages within the state. Estimated data are indicated by "E." Estimated data from air-observed markers are indicated by "A."

The average snow water equivalent is given if there are 5 or more years of record. This is done by comparing it with the snow water equivalent of a course that has a complete record during the average base period.

For instance, a short-record course has 8 years of record on March 1. The average snow water equivalent for a short-record course for the 8-year period is 10 inches. The average for the long-record course for the same 8-year period is 12 inches. The average for the course of longer record is 14.4 inches for the 15-year base period. Therefore, the estimated average for the course of shorter record for the 15-year base period is 10 inches divided by 12 inches multiplied by 14.4 inches--or 12 inches (10/12 x 14.4 = 12). This comparison should be established with a course that closely correlates with the course of shorter record.

Soil Moisture Tables.--The latest available soil moisture data are used in the report. The tables show the name of the soil moisture station, the soil profile depth, the total soil moisture-holding capacity (field capacity) in inches of water, the date of measurement, the total available soil moisture in the profile in inches of water, the same data for a similar date a year ago, and the average. Since soil moisture records are relatively short, the average is for the period of record. When a 15-year base period is available, soil moisture station averages are compatible with the snow-course average period. If there is space, the code number and elevation of the soil moisture station are included.

Precipitation Data Tables.--Basic precipitation data pertinent to water supply forecasting collected by SCS and cooperators are published in state water supply outlook reports. Summaries of precipitation data may be shown in special tables or described in narrative form.

The minimum information includes the name of the station, the current date of measurement, the precipitation in inches to one decimal point for the past month, the average for the month when 5 or more years of record are available, the precipitation in inches from a beginning fall date such as October 1 to the date of the report, and the average for this period. Additional information may include the code number and elevation of the station and the percentage of seasonal average.

Reservoir Storage Data Tables.--Reservoir storage data are listed for reservoirs having as little as 5,000 acre-feet in active capacity. As a minimum, reservoir storage tables show the name of the reservoir, the usable capacity, the present storage, and average storage. Storage on or about the same date a year ago is desirable. The listing should be by major basins within the state. Averages for reservoir storage are computed in the same manner as snow water equivalent.

Data in graphic form may be used to illustrate relative storage within a basin. A bar chart with the present percent of capacity versus the average storage in percent of capacity is usually shown. Usable capacity of the reservoir and related contents in storage figures are generally those used by the operators of the reservoirs.

Streamflow Forecast Tables.--Since streamflow forecasts are based on snow water accumulation as a major variable, forecasts are for the period in which there is runoff from snowmelt. For most areas of western

United States the period is from April through July. Some forecast periods begin the first of February and some extend through September. In the Southwestern states and nearby areas of adjacent states, snowmelt may be over by the end of May.

As a minimum, the streamflow forecast tables show the name of the gaging station for which the forecast is made, the forecast period, the amount of the forecasted flow, the average flow for the period in acre-feet, and the forecast in percent of average. A column for comparable flow figures for the previous year is desirable. If forecasts are made for different periods, they are shown on separate lines.

Special forecasts such as dates of occurrence of peak or specific rates of flow can be shown as footnotes on the forecast page or reported in separate tables. Other footnotes show the operations included above the station that affect the amount of flow.

Adjective forecasts of water supply outlook or streamflow, normally used for small ungaged streams, are included in the narrative or in special notices. Terms such as excellent, good, fair, and poor are used to describe water supply conditions.

Local Reports

The local or small watershed water supply outlook report is considered a supplement to local and statewide news releases. The format should be adjusted to meet local conditions. It may or may not include basic data but should list in tabular and narrative form a summary of the data.

These reports may be prepared by area and work unit offices in consultation with the state office. The snow survey supervisor provides the forecast outlook and determines general format. The emphasis in these reports is on local water conditions. Coverage should be commensurate with the needs of irrigated areas and the ability to provide adequate forecast information.

Westwide Report

The westwide water supply outlook report is designed for reporting in broad terms water supply conditions in the Western states. The report does not contain basic data, except storage in principal reservoirs. Engineering Memorandum 49, Snow Survey - Responsibilities and Data Exchange, dated April 5, 1965, specifies the information required from state offices for this report.

The data section of the report shows accumulated snow water equivalent to date, in percent of average and the past year for major subwatersheds in the Western States. Streamflow forecasts for the principal stations are listed in thousands acre-feet and percent of average. The flow for the forecasted period of the past year is listed if available. The forecasts shown are the same as those listed for the station and period in the State reports.

A reservoir table lists storage in major reservoirs in the Western states. The general status of reservoir storage by state or large watershed may be shown in graphic form.

The narrative section of the report, based on the narrative section of state reports, describes the impact of water supply along larger streams and unusual conditions affecting smaller irrigated areas.

Engineering Memorandum 49 also prescribes methods of coordinating streamflow forecasts between states along interstate streams. Details are provided by WSFU. The general guideline for deviation between forecasts is one standard error plus or minus from the least square line of past flow records. These procedures in simplified graphic form are provided to downstream state snow survey supervisors for preparation of forecasts. Disagreements between snow survey supervisors are resolved by WSFU.

Basic Data Summary

Each state publishes a listing of basic data every 5 years including measurements of snow courses and soil moisture stations. A representative portion of data from automatic stations should be reported in these summaries. As a minimum, data for the middle and last day of the month are reported. The general format is shown in figure 5-8. Covers and title pages are similar to those used for the water supply outlook report. The title is "BASIC DATA SUMMARY FOR (STATE)."

In the future, state basic data summaries will not contain more than 10 years of record in any one volume. If there is a complete revision of record of a station, this total record will be shown in a revised section. If the number of revisions is substantial, a complete reprinting of a former summary will be done.

On an annual basis all data is combined into a westwide summary of basic data as a temporary summary. Data for this report are taken directly from state water supply outlook reports with corrections that are available at the end of the snow survey season.

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CHAPTER 8. MAINTENANCE OF INSTALLATIONS AND EQUIPMENT

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CHAPTER 8. MAINTENANCE OF INSTALLATIONS AND EQUIPMENT

Installations

Snow Courses

Every snow course should be visited during the snow-free months at least once each two years. On such visits, marker poles are installed, straightened, or painted, and marker signs are replaced if necessary. In maintaining any snow course, the ground surface is cleared of rock, fallen trees, stumps, and brush 3 to 5 feet in all directions from each point selected for sampling. In some types of ground cover, such as vine maple, clearing may be required annually.

Aerial Markers

Aerial markers are subject to damage from snowloads, snowcreep, and animals. It is usually the lower bars that are damaged. Although snow-creep often bends the pipe, it is more likely to bend the marker off the vertical. This kind of damage should be checked for each year and corrected. The crossboards and angle braces should be painted every other year. Since the markers are to be observed from the air, the surrounding area should be cleared upon installation and kept clear. Brush should be removed for 10 to 15 feet around the marker and trees even farther back.

Trails

Maintenance of trails to snow courses and aerial markers is necessary. Roads and trails that are well defined in the summer often are completely obscured by snow. Trail blazes placed too near the ground are buried under the winter snowpack. Even the most experienced woodman can become confused while traveling in blizzards and fog. One way to mark trails is to use timber marking paint and a paint gun. This paint has lasting qualities; an orange color is preferred because it is visible for a considerable distance. Using standard snow survey trail marker signs is recommended.

Snow Pressure Pillow Sites

Butyl-rubber pillows have been in service for 10 years at some locations. Butyl rubber is long lasting under field conditions if there is no damage other than that from normal deterioration. Similar service can be expected from neoprene or sheet metal.

The life of metal pillows can be extended by painting, particularly if galvanizing or rust-preventive paints or paints containing coal tar epoxy are used. Also, electrolysis of the metal pillows is minimized if magnesium anode rods are placed in the soil near the pillows and connected to them with copper wires.

Soil Moisture and Temperature Sites

Soil moisture and temperature measurements are taken with an ohmmeter. This meter should be repaired only by a qualified radio repair shop. Instructions for replacing batteries--the usual maintenance required--are supplied with the meter.

Soil moisture stacks should not be disturbed after installation. Maintenance consists of keeping the terminals free of corrosion and protecting the stand pipe and wires from damage. If there is electrical failure of a unit, it must be replaced. Vegetation around the site should be controlled by limited pruning only; brush should not be removed.

Precipitation Sites

Storage gages, the only type discussed here, range from metal or fiberglass stand pipes 20 feet high to oversized precipitation cans with 8-inch or larger orifices. Maintenance is generally limited to patching bullet holes, repainting metal cans, and keeping antifreeze and oil in the gage. The orifice should be checked periodically to see that it is still level and not out of shape. The snow shield should be free-swinging and properly alined around the orifice. The area around the precipitation cans should be checked for trees that might fall and damage the gage. These trees should be removed.

Shelter Cabins

Cabin windows should have shutters and screens. Shutters on the outside are often hard to remove, but they prevent bear damage. If shutters are on the inside, the outside must be protected by heavy gage hardware cloth or equivalent. Cabin doors and access ways must be tight yet free-swinging. The roof must be checked to see that the shakes or shingles are in good condition. Linseed oil will preserve both siding and roof.

Equipment

Travel

Oversnow Machines

Oversnow machines are to be maintained according to manufacturer's instructions (see ch. 4).

Skis and Snowshoes

Skis or snowshoes in good repair are important pieces of equipment to a snow surveyor traveling on foot in the back country. To maintain them takes only a little time and effort. The skis should be strapped together with a 1-1/2-inch block of wood at the balance point. Snowshoes should be strapped together with the turned-up section facing in opposite directions. Before and after each trip, they should be inspected for damage and repaired.

Skis.--All edge and binding screws must be kept tight. Cables must be replaced if broken, kinked, or badly worn. Toe straps on "bear trap" bindings should not be torn (carry extras). The ski base lacquers should not be chipped or gouged. Skis should be repaired if necessary, blocked at the balance point and tip, and stored in a cool, dry place. At the end of the season, the tops, if marred, should be refinished. The skiiing surface should be refinished too if there has been substantial wear during the winter.

Snowshoes.--Snowshoes must be checked closely to see that the rawhide webbing is not broken or worn. Broken lacing must be repaired by splicing or be replaced. Snowshoes should be revarnished after each trip with a good marine or "Spar" varnish, and both sides of the webbing and all the frame should be covered. The harness must be kept well oiled with "Neats Foot" oil or other good leather preservative. Snowshoes should be lashed together with the tips apart in a cool, dry place and out of reach of rodents when in storage.

Sampling

The proper care and maintenance of snow survey tools is absolutely essential for reliable results. Clean, well-waxed snow tubes and a sharp cutter can eliminate many difficulties in obtaining accurate samples. The most important part of this maintenance is to see that the tube sections are covered with a thin coating of hard clear wax.

Sampling Tube Sections

Before applying any type of wax, the tubes should be cleaned of all varnish, shellac, or other coating. If solvents or paint and varnish removers are used, this remover must be rinsed off with a naptha solvent and wiped dry with a clean cloth. Hot oakite, a strong washing powder with sodium trisulphide, will do a good job on shellac.

A circular wire brush attached to a 3-foot rod helps in cleaning the inside of the tubes. If a 1/4- or 3/8-inch electric drill is available, this cleaning job is easy. Clamp the drill in a vise, insert the rod with the wire brush on the end, start the drill, and run the brush through the tube by holding the tube with leather gloves. A wire hand brush does a good job on the outside. A circular wire brush on a bench grinder hastens the process. When the tubes are clean of all grease and old paint, varnish, or shellac, waxing can be started.

Build a swab on the end of a 3-foot stick, saturate the swab and run it down the inside, coating all the metal. Apply evenly and, when dry, polish with a clean swab on the inside and also on the outside. Be sure to polish well inside and out. Apply a second coat.

Self-polishing liquid wax is probably the simplest to apply. Automobile liquid wax, liquid floor wax, or liquid furniture wax may be used. Two or three coats should be enough. Do not use antiskid waxes. Silicone and teflon waxes, such as used in ovens and on cooking utensils, are very effective.

Paste waxes have been found to work well also and are easily applied on a clean tube with swab and rags. Simonize car wax is probably the hardest form of the paste waxes and is applied with a wet cloth (follow directions on can). Polishing is all-important.

Ordinary paraffin does a fine job of waxing if applied on a hot tube. Handle the tube with gloves; melt some paraffin through the slots and let it run down the tube spirally by turning the tube. Quickly spread the paraffin over the inside surface with a prepared swab on the end of a stick 6 or 8 inches longer than the tube; keep the whole tube warm while the swab is run back and forth quickly. Polish the inside until it is shiny. Also, the cake of paraffin may be rubbed up and down the outside of the hot tube and the small amount of paraffin spread with a cloth and briskly rubbed to polish it. One thin coat applied by this procedure usually lasts through several survey trips. Solid icy snow may require a wax job after each trip. If power tools are available, these waxing jobs are done quickly, and a good high polish is obtained, but care must be taken when using power tools.

Cutter Bit

The cutter bit is made of steel and usually is case-hardened. It can be sharpened with a fine cut file. This cutter should be inspected and sharpened occasionally with the file to get maximum cutting efficiency on ice layers within the snowpack. When filing the cutter, follow the pattern of the old cutter that is sharpened like a rip saw.

The teeth on the cutter may be broken off or bent inward by striking rocks. If any teeth are broken, the cutter should be removed and a new one inserted. Bent teeth can be straightened or filed smooth to the same diameter of the shoulder on the inside of the cutter. The cutter is held in place at the end of the first section (0 to 30 inches) of tubing by a heat-shrunk fit.

To remove the cutter, first, be sure to have a new cutter handy and ready to insert immediately after sliding the old cutter out. Lightly clamp the tube in a vise, using several wraps of heavy cloth or innertube around the duraluminum tube where held by the vise. Heat the duraluminum tube around the cutter with a blow torch flame or other gas torch. At the same time, grip the old cutter with a pair of pliers and continually pull outward while applying the heat around and around the tube. A small wet, cold rag wadded up inside the cutter (but not touching the tube) helps to keep the cutter from heating and expanding with the outer metal. The outside metal of the tube expands enough for the cutter to slide out.

Quickly grasp the new cutter by the teeth end and push it into place; be sure the cutter is up against the end of the tube. Remove heat and let tube cool. After the tube has cooled, try turning and pulling the cutter bit to see if it will come out. There is enough difference in the machining of various cutters and tubes that sometimes a cutter pulls out easily.

CAUTION: Do not use an acetylene welding torch for this process since it will melt the aluminum instantly.

Coupling Threads

During the years since snow surveying began, several instrument companies and machine shops have made up snow sampling tubes. Unfortunately, the threads of the couplings from each shop are a little different, not much but enough so that the threads of one bind if used with a different make. It is important to keep sections of the same make of tube together in one set.

Oftentimes the threads of a particular set of tubes fit too tightly for easy uncoupling. The threads can be ground or lapped out with a little valve-grinding compound; do not hurry the lapping process. Use plenty of oil with the compound and turn the tubes back and forth many times. Clean out the compound with an old toothbrush and naptha solvent. Wipe the threads dry and try for an easy fit. A little gunslick grease or petroleum jelly is best if a lubricant is required.

Couplings

Occasionally a coupling becomes twisted or pushed down so that the graduation between tube and coupling is less than standard. The couplings should be slipped back into place by a machine shop or the manufacturer.

Snow Tube

Dents and cave-ins caused by carrying and using the driving wrench can be corrected with a mandrel or a metal plug the same size as the inside diameter of the tube. The tube is then struck with a soft hammer to draw the dent up; a steel hammer will dent metal and draw it the wrong way.

The tube, if snow sticks to the inside while sampling, should not be cleaned by hitting the side of the tube against trees, marker posts, or other objects that will dent it. The tube should be cleaned by loosening the snow through the slots with a case knife or other tool. When the plugs of snow have been broken up and removed, the loose snow can be cleaned out by drawing a cloth through the tube from the top end and out through the cutter end. A strong cord such as nylon is tied to the cloth with a small weight such as a spanner wrench to the other end. The weight can be dropped through the tube.

Spanner Wrench Holes

Holes to fit the spanner wrench pegs should be drilled far enough down the sloping portion of the coupling to miss the long support sleeve coming into the threads from the next section. These holes are usually nine thirty-seconds of an inch in diameter. The several sections of the set should be examined to see that one of these holes is near the top and bottom of each section. These holes are useful in the event that the couplings become screwed together tight when using the driving wrench.

Spring Balance
The spring balance probably is the most delicate part of the equipment. An occasional cleaning and calibration check is necessary for satisfactory use. The balance should run free. No grease or oil should be used. If dirt or grit collects between the two sliding sleeves, they should be cleaned with solvent and wiped dry with a clean cloth.

The mechanism of the spring balance is simple. The outer shell can be removed by taking out the screw or screws around the top of the cylinder. Gently snap the spring once or twice, and the top ring post will slip off the outer cylinder. Stretch the spring down about 3 inches and insert a screwdriver or a nail in the spring coil. Relax the spring tension and punch out the round pin to free the ring post. After the nail supporting the spring is removed, the spring will drop inside. To remove the bottom pigtail post, use a 9- or 10-inch piece of 1/4-inch round rod as a punch. Hold the inner cylinder in hand and tap on the long 1/4-inch punch, driving off the pigtail post. The spring can be unscrewed from the round pin and the inside scale can be disassembled for cleaning or repair.

When the balance is being assembled, the zero point of the springs can be modified by adding a short link of stout steel wire or 1/8-inch steel welding rod between the loop in the top end of the spring and the small pin through the top ring post. The ends of this link MUST be tight together. It is often necessary to grind the sides of the upper half of this link so that it swings freely. This little adjusting process makes it impossible to read ZERO on the scales even with one tube, provided the link is a little long. This adjustment does not hamper the calibration of the balance although there is a little loss of capacity at the upper end with heavy weights. If the balance is used to measure 2 or 3 feet of low density snow, however, it is adjusted so that there is always a fairly large plus value to TARE weight and never close to zero. This adjusting process is not necessary on all balances, only on those on which the surveyors are prone to use zero as a tare weight.

Telemetry

Maintenance on radio transmitting, receiving, and associated electronic devices must be done by radio technicians who have a Federal Communication Commission (FCC) license, second class or better. Maintenance also may be performed by radio technicians of SCS or other federal agencies under agreement or mutual arrangement.

SCS contracts and agreements may be developed according to procedures in the Administrative Services Handbook. FCC rules and regulations require a periodic check of transmitting equipment to determine that it is on frequency, has proper band width, is free from spurious radiation, and is otherwise functioning in accordance with operating specifications. As a general rule, SCS equipment is checked periodically by a qualified radio technician and a record kept for inspection.

CHAPTER 9. ADMINISTRATION

CONTENTS

CHAPTER 9. ADMINISTRATION

Workload and Scheduling

Total Workload

The planning, management, and operation of snow surveys and water supply forecasts is a complex activity. There are jobs that must be done on a time basis and by season, and there are all kinds and levels of work, some done by SCS employees and some by cooperators. The snow survey supervisor must have an intimate knowledge of the entire operation, the level and grade of the work to be performed, the schedule, and the man-hours required for each operation or phase of the total job. He should have an annual operations guide that schedules the work month by month by position beginning January 1.

Table 9-1 shows most of the functions in routine snow surveying and water supply forecasting. The total man-day requirements by grade can be determined by filling in estimates of time in the appropriate grade column. Study of the results should provide a basis for balancing the workload according to level of responsibility and for setting priorities for items of work if the total load exceeds available manpower. The study can also be used to determine those operations that can be done more efficiently or that can be eliminated to bring the total workload in line with the available personnel. The study may indicate the need for additional help.

A more detailed breakdown is required for scheduling some phases of the job such as snow course and related measurements.

Scheduling of Data Measurements

The schedule of data measurements provides control and direction over all field operations during the water supply forecasting season. It authorizes the work and gives the time and place for collecting the data.

In general, snow course and related measurements are obtained during the 4 days before the first day of the month from January through June. Special conditions may require midmonth or early- or late-season measurements. Among these are locations where the snow melts in advance of the usual melting season and where forecasts during the snowmelt season need to be refined.

Factors Affecting Scheduling

The distribution and accessibility of snow courses, the employees making surveys, and the required time are factors to consider in planning a schedule of operation. The mode of transportation, such as helicopters, oversnow machines, and foot travel, is also a pertinent factor. A well-balanced schedule should be planned that permits the orderly collection of data and enough time for quality work. The possibility of equipment breakdown or other contingencies should be considered. It is important that all scheduled snow courses be measured and at the appropriate time.

Table 9-1.--Workload analysis

Snow survey unit work activities	Soil cons. GS-12	Soil cons. GS-11	Clerk-steno GS-4 or 5	Eng. aid GS-5
		(Man-days)		
1. <u>Forecast development and release</u>				
Scheduling measurements				
Field surveys				
Note checking				
Preparing forecasts				
Preparing news releases				
Preparing release of bulletins				
Providing assistance at local levels				
Preparing for and participating in forecast meetings				
2. <u>Analysis of data and formula improvement</u>				
Determining forecast accuracy				
ADP processing - data collection				
Developing and updating formulas				
3. <u>Records management</u>				
Snow course biography				
Preparing snow course maps				
Posting and updating data records				
Reporting accomplishments and time				
Photo canopymeter records				
4. <u>Installation</u>				
Snow courses				
Aerial markers				
Soil moisture stacks				
Precipitation gages				
Automatic systems				

Table 9-1.--Workload analysis--Continued

Snow survey unit work activities	Soil cons. GS-12	Soil cons. GS-11	Clerk-steno GS-4 or 5	Eng. aid GS-5
		(Man-days)		
5. Maintenance				
Data collection equipment				
Data collection sites				
Vehicles				
Skis and snowshoes				
6. Staff functions				
Training				
Professional and technical meetings				
Staff meetings				
Public relations				
Information and education (snow survey)				
Long-range planning				
Budget development and analysis				
7. Other duties				
Preparing special material and reports				
Coordinating data and forecasts with other agencies				
Developing equipment				
8. Holidays, annual and sick leave				

Requirements for Water Supply Forecasting.--The reason for obtaining basic data is to make streamflow forecasts and to provide water supply outlook information. One principle in scheduling is that all basic data should be gathered near the time of maximum snow accumulation, March 1, April 1, or May 1, depending on the local snowfall regime.

Early-season (before March 1) snow measurements are few because most of the snow accumulates later. Early-season measurements are also more difficult to obtain when days are short, temperatures are lower, and snow is soft, making travel by foot, oversnow machine, or even aircraft more difficult. But a few snow measurements distributed over a state or watershed in midwinter can indicate general snowpack and soil moisture

conditions. Reasonable appraisals of outlook can be made with relatively few measurements considering the deviations from normal that can occur late in the season.

Late-season (May 1 and later) measurements, which are relatively easy to obtain, are scheduled to provide data on abnormal snowpack buildup or depletion during spring, and they provide the best data for adjusting forecasts of probable water supply. These measurements are required for operating multiple-purpose reservoirs efficiently, assisting with estimates of peak flow stages, and for making various kinds of late-season flow forecasts. As the number of water-control structures increases, the more important late-season measurements become. Late-season measurements are made on courses at relatively high elevations where snowpack persists into June in at least half of the years of measurement.

Midmonth measurements are scheduled for areas where melting may occur, and they have a substantial influence on the forecaster's ability to forecast the amount of early-season runoff. A few midmonth measurements in March, April, and May may be desirable to maintain a general inventory of snowpack conditions. The number of measurements and the schedule depend on the water-use plans that may be changed because of a substantial deviation from normal in the rate of snowpack accumulation during the spring. These measurements are most important in the Southwest and the southern Rockies where a large proportion of the seasonal snowfall may occur after March 1, April 1, or May 1.

Accessibility.--Accessibility is a major factor in scheduling measurement on snow courses and often determines the location of data-collection sites. Only network data-collection sites that are accessible and can be measured as scheduled should be operated.

Manpower and Equipment.--Reliable snow measurements and a high probability of obtaining them on a regular schedule are possible only if reasonable provision has been made for trained manpower and suitable oversnow equipment.

Time for Collecting Data

Typical Scheduling.--As a guide, a certain percentage of a snow survey network needs to be measured as follows: not more than 10 percent before January 1, 10 to 25 percent near January 1, 40 to 75 percent near February 1, 75 to 100 percent near March 1, 90 to 100 percent near April 1, 75 to 100 percent near May 1, and less than 25 percent near June 1. Midmonth measurements can be 25 percent or less of the total network. Snow courses and related installations at lower elevations are included in the above percentages. Exceptions to this general schedule are in the mountains at lower elevation in the Southwest where midmonth measurements are necessary for more frequent forecasts.

Special Scheduling.--Soil moisture stations should be measured in late fall just before the permanent snowpack starts to accumulate and at the same time the snow course measurements are scheduled for the same routes.

Precipitation gages at high altitudes should be measured on a monthly basis if practical. As a minimum, measurements should be made on or about October 1 and November 1 and at the same time snow courses on the same route are measured. To assist in evaluating conditions affecting runoff during the snowmelt season, monthly measurements from April 1 through July 1 have the next highest priority.

Preparation of Schedules

Tentative schedules, based on the schedule of the previous season and planned changes in requirements, should be prepared by the snow survey supervisor by July 1 of each year. They should include proposed dates of measurement, available equipment (oversnow machines, aircraft, or remote sensing installations), recommended cooperative assistance, and any special instructions. Local arrangements should be made at appropriate SCS areas and work units. Comments from area offices should be received so that a formal schedule can be prepared by October 1. Agreements or letters of understanding regarding cooperative funds or services with federal, state, and local agencies should be completed before the snow season begins. Agreements with other federal agencies which involve SCS in more than one state are coordinated by WSFU.

Distribution of Schedules

Schedules and instructions approved by the state conservationist are distributed to area and work unit offices in that state and to appropriate cooperators providing services. WSFU should receive copies.

Radio Communication

Use of Equipment

The snow survey and water supply forecasting activity requires the use of radio voice communication and radio telemetry. Each type of operation requires equipment that is peculiarly suited to its needs and purposes. Installation and operation must adhere to federal rules and regulations governing the licensing of stations and the authorization for use of transmitting frequencies.

Rules and Regulations

The rules and regulations governing the use of radio equipment are covered in the Code of Federal Regulations, Title 47 - Telecommunication. The subject matter in Chapter I (revised January 1, 1965) follows:

Subchapter A--General--Parts 0 to 19
Subchapter B--Common Carrier Services--Parts 20 to 69
Subchapter C--Broadcast Radio Services--Parts 70 to 79
Subchapter D--Safety and Special Radio Services--Parts 80 to End

This information provides the basis for the regulation and administration by the Federal Communication Commission (FCC) of radio frequencies assigned for public use.

462-302 O - 72 - 13

The Interdepartment Radio Advisory Committee (IRAC) regulates the assignment of frequencies that have been provided for federal use. This group is composed of members representing federal departments having an interest in radio communication.

Frequency Assignments

A frequency and station authorization is necessary before transmitting equipment of any kind can be operated. Since the operating frequency must be known before specified equipment is delivered, purchases of equipment should not be completed before obtaining a station and frequency authorization.

If a frequency or frequencies that have been set aside for telemetry of hydrologic data are requested, the requests must be reviewed and cleared by the Hydrology Committee of the Water Resources Council in addition to the IRAC (see fig. 9-1 for procedure). All requests for frequency and station authorization should be submitted according to instructions in Administrative Services Memorandum AS-30 (rev. 4) dated November 29, 1971. A typical radio frequency and station authorization is shown in figure 9-2.

Figure 9-3 lists symbols relating to types of radio emission. The numeral on the authorizations preceding the emission symbol prescribes the band width.

The class of station generally is given as MO (mobile station) or FX (fixed station). The most commonly used symbols for classes of stations follow:

FB	Base Station. A land station in the land mobile service carrying on a service with land mobile stations
FBR	Base Station Repeater (typically, land mobile in-band repeater)
FC	Coast Station. A land station in the maritime mobile service
FL	Land Station. A station in the mobile service not intended to be used while in motion
FLR	Land Station Repeater
FX	Fixed Station (for radiocommunications between specified fixed points)
FXH	Hydrologic and Meteorological Fixed Station. A fixed station the emissions of which are used for the automatic transmission of either hydrologic or meteorological data, or both
FXR	Fixed Station Repeater (In the land-mobile service, a control or link repeater)
FXHR	Hydrologic and Meteorological Fixed Station Repeater
LR	Radiolocation Land Station. A station in the radiolocation service not intended to be used while in motion
MA	Aircraft Station. A mobile station in the aeronautical mobile service on board an aircraft or an air-space vehicle
ML	Land Mobile Station (typically vehicular and portable radio stations)

June 2, 1970

Water Resources Council
Hydrology Committee

PROCEDURE FOR COORDINATING RADIO FREQUENCY ASSIGNMENTS
FOR COLLECTING HYDROLOGIC DATA

1. The Hydrology Committee of the Water Resources Council (WRC) recommends to the Interdepartment Radio Advisory Committee (IRAC) and to the Federal Communications Commission (FCC) the assignment of specific radio frequencies in the bands allocated for use jointly by Federal and non-Federal agencies for transmission of hydrologic and meteorological data for hydrologic purposes[1/]. Specific frequencies are:

A.	169.424 Mhz	170.225	171.025	171.825
	169.450	170.250	171.050	171.850
	169.475	170.275	171.075	171.875
	169.500	170.300	171.100	171.900
	169.525	170.325	171.125	171.925
		406.025	412.625	
		406.075	412.675	
		406.125	412.725	
		406.175	412.775 Mhz	

Transmitters and receivers employed on these frequencies are required to meet technical standards established by the Director of Telecommunications Management (IRAC) for Federal stations or by the FCC for non-Federal stations.

B. With respect to previously allotted hydrologic frequencies 169.575, 170.375, 171.175, 171.975, 406.050, 406.150, and 406.250: Hydrologic stations authorized for operation on one of these frequencies prior to May 8, 1962, will not be required to change frequency into the exclusive hydrologic bands. In regard to an existing network operating on these frequencies, additional stations may be incorporated, or location of one or more stations may be changed, without change of frequency. However, information required in paragraph 2A below will be provided for all new and relocated stations.

2. The Hydrology Committee, through its Hydrologic Radio Frequency Work Group, coordinates requests for frequency assignments for all hydrologic purposes within these bands. In order that this coordination will be effective, the following plan of operation will be followed for <u>Federal</u> agencies:

1/ Reference - IRAC Minutes, November 7, 1946, Meeting, Items 18 and 19.

Figure 9-1.--Procedure for coordinating radio frequency assignments for collecting hydrologic data.

A. A Federal agency desiring to secure a hydrologic frequency assignment from IRAC will prepare a memorandum describing the proposed plan of operation, using the format described below. The proposal will be submitted through the Hydrologic Radio Frequency Work Group member, or, in the case of a Federal agency not serving on the Work Group, directly to ESSA Weather Bureau, Attention: Hydrologic Radio Frequency Coordinator (Chairman). An original and nine copies of the memorandum and the attachments will be submitted. The following information will be furnished for each station to be installed:

(1) Name, type, and location of station. Type would be relay, command station, or sensing; location, latitude and longitude.

(2) Kind of hydrologic data to be transmitted (river stage, precipitation, etc.)

(3) Frequency or frequencies required. Indicate transmitting (T) and receiving (R) frequencies.

(4) Output power of transmitter.

(5) Antenna Characteristics: (a) Antenna name (generic preferred); (b) Orientation (degrees from true North or non-directional, as appropriate); (c) Gain (nominal), dB; (d) Site (terrain) elevation above MSL (feet); (e) Antenna height above terrain (feet).

(6) Operation schedule; i.e., on call, automatic for 15 minutes each hour, manual hourly under specified conditions, etc.

(7) Necessary band width of emission in kilohertz.

(8) Type of emission (one of the following):

Symbol	Type
A	Amplitude modulation.
F	Frequency (or phase) modulation.
P	Pulsed emission.

Note: The above emission characteristics may be expressed in symbol form such as 16F2, for "bandwidth - type of emission - type of transmission," in that order.

Figure 9-1.--Procedure for coordinating radio frequency assignments for collecting hydrologic data--Continued.

(9) Type of transmission (one of the following):

Symbol	Type
1	Telegraphy without the use of modulating audio frequency.
2	Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by on-off keying of the modulated emission.
3	Telephony.
9	Composite transmissions and cases not covered by the above.

(10) Map showing location of transmitting and receiving stations and limits of operational area. A coordinate grid (latitude and longitude) will be shown on the map.

(11) Justification of installations by explaining the use of the data to be collected and the reasons why radio is to be used in lieu of land lines.

(12) Cooperating agencies, if any.

B. The Hydrologic Radio Frequency Coordinator will send a copy of the request to each Work Group member for review and comment concerning the effect upon his agency's operations and an appraisal as to the appropriateness of using the hydrologic frequency spectrum for the purpose intended. The Work Group members will check the request against other current applications and records of existing installations. When clearance from all Work Group members has been received, the Coordinator will advise the applicant--on behalf of the Hydrology Committee--that formal application may be made to IRAC for frequency assignment. A copy of the Coordinator's clearance letter should be used by the applicant to indicate that coordination has been accomplished.

C. Applications to IRAC or FCC for frequency assignments must be made within three months following Hydrology Committee action; otherwise, the request must be resubmitted to obtain clearance.

D. If, under 2.B, Work Group members present objections to the applicant's proposal, the Coordinator will recommend counterproposals. If a counterproposal is acceptable, he will then advise the applicant of required revisions to the original proposal in order to overcome the objections. If Work Group members cannot reach agreement on any request, that particular case will be referred to the full Hydrology Committee for decision.

Figure 9-1.--Procedure for coordinating radio frequency assignments for collecting hydrologic data--Continued.

E. Any modification of existing networks or individual stations--where the data supplied under 2.A(1) through (12) are changed--shall be submitted in writing to the Hydrologic Radio Frequency Coordinator with an original and nine copies. According to the nature of the change, the Coordinator will effect whatever coordination is considered necessary.

F. When authorized frequency assignments are no longer required by Federal agencies, this fact should be reported through individual agency channels to the appropriate IRAC representative.

3. Proposals for frequency assignments for non-Federal agencies must provide all the information required under 2.A. Such requests will be processed in accordance with paragraphs 2.B, 2.C, 2.D, and 2.E. If the Committee recommends favorably, the Coordinator will advise the applicant that there would be no objection to his making formal application to the FCC for license. A copy of this letter should be attached to the FCC application as proof that coordination has been accomplished. If a license is granted, the responsibility for the applicant's adherence to all legal requirements of the license rests with the FCC. In the event of unfavorable action by the Committee, the applicant and the FCC will be so notified.

4. The Hydrologic Radio Frequency Coordinator will report, for the record, at each meeting of the Hydrology Committee, on the status of pending and completed coordinations. Every effort will be made to expedite actions if the need is so stated in the original request.

Figure 9-1.--Procedure for coordinating radio frequency assignments for collecting hydrologic data--Continued.

U.S. DEPARTMENT OF AGRICULTURE - SOIL CONSERVATION SERVICE

BOZEMAN, MONTANA HYDROLOGIC TELEMETRY SYSTEM

	STATION NAME	LAT/LONG	Tx POWER (kw)	Tx FREQ. (MHz)	Rx FREQ. (MHz)
1.	BOZEMAN, MONTANA (Base Station)	45°41' N 111°02' W	0.0050	169.450	171.075
2.	EAGLE HEAD (Repeater)	45°13' N 111°08' W	0.0050	171.075	169.450
3.	LICK CREEK (Repeater)	45°31' N 110°57' W	0.0050	171.075	169.450
4.	TAYLOR PEAK (Data Site)	45°01' N 111°27' W	0.0050	169.450	171.075
5.	LICK CREEK (Date Site)	45°30' N 110°58' W	0.0050	169.450	171.075
6.	SHOWER FALLS (Data Site	45°24' N 110°57' W	0.0050	169.450	171.075

NOTE: Emission is 16F2 for data transmission and 16F3 for test and maintenance.

Figure 9-2.--Radio frequency and station authorization.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
Washington, D. C. 20504

APPLICATION FOR FREQUENCY ASSIGNMENT ACTION

RECORD MARK	AGENCY SERIAL NO. 10	DATE 6
	A 701343	700731

LINE LABEL	LIST FREQUENCY 11	LIST ASSIGN. NO. 10
A01		

LINE LABEL	TYPE OF ACTION / CLASSIFICATION	FREQUENCY 11	AGENCY/BUREAU 4	NET CONTROL 5	RELATED ACTION 6	ASSIGN. TYPE	JUSTIFICATION 5	JOINT APPLCTN BUREAU 4	TRUNK 6	EXP. DATE 4
F01	NE	M169.45						S1		

LINE LABEL	STATION CLASS 4	EMISSION 7	POWER 9	NOTES 4
E01	FXH	16F2	0.005	
E02	FX	16F3	0.005	

FOR AGENCY USE ONLY

DEPARTMENT OF AGRICULTURE

ASSIGNMENT APPROVED DATE 23 OCT 1970

DEPARTMENT OF AGRICULTURE REPRESENTATIVE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

SUPERSEDES A670726

TX

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	TIME 4	CALL SIGN 6	ANT. DIMENSIONS 24
T01	MONT	BOZEMAN		4541XXN11102XXW			180	3		10GCRHRRFLCPPD4800H0056T

RECEIVER

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	RSN 3	AREA 3	CALL SIGN 6	ANT. DIMENSIONS 24
R01	MONT	LICK CR		4531XXN11057XXW			340				09GCOLLINEAR 0806H0025T
R02	MONT	EAGLEHED		4513XXN11108XXW			010				09GCOLLINEAR 0970H0015T

LINE LABEL	CIRCUIT REMARKS 40
C01	*NRM,XXXXX,SCS218
C02	*DOC,I6712844
C03	*TPT,R

LINE LABEL	SUPPLEMENTARY DETAILS
S01	ROUTINE. Update. Hydro Committee letter dated April 22, 1970.

CERTIFICATION: THIS IS TO CERTIFY THAT THERE IS AN IMMEDIATE OR EARLY NEED FOR THE REQUESTED ASSIGNMENT, THAT THE FREQUENCIES NOW AUTHORIZED FOR USE BY THIS AGENCY HAVE BEEN EXAMINED, EXISTING AUTHORIZATIONS DO NOT MEET THIS NEED, AND THE ADDITIONAL AUTHORIZATION REQUESTED OR ITS EQUIVALENT IS ESSENTIAL TO MEET THE AGENCY'S REQUIREMENTS SATISFACTORILY

SIGNED: Virginia M. Martin
Alt. REPRESENTATIVE, FREQUENCY ASSIGNMENT SUBCOMMITTEE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

OT FORM 86A JAN 70 (NEW OR NOTIFICATION)

Figure 9-2.--Radio frequency and station authorization--Continued.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
Washington, D. C. 20504

APPLICATION FOR FREQUENCY ASSIGNMENT ACTION

RECORD MARK	AGENCY SERIAL NO. 10	DATE 6
	A 701342	700731

LINE LABEL	LIST FREQUENCY 11	LIST ASSIGN. NO. 10
A01		

LINE LABEL	TYPE OF ACTION / CLASSIFICATION	FREQUENCY 11	AGENCY BUREAU 4	NET CONTROL 5	RELATED ACTION 6	ASSIGN. TYPE	JUSTIFICATION 5	JOINT APPLCTN BUREAU 4	TRUNK 6	EXP. DATE 4
F01	NU	M171.075						S1		

LINE LABEL	STATION CLASS 4	EMISSION 7	POWER 9	NOTES 4
E01	FXBR	16F2	0.005	
E02	FXR	16F3	0.005	

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DEPARTMENT OF AGRICULTURE
ASSIGNMENT APPROVED DATE 23 OCT 1970
DEPARTMENT OF AGRICULTURE REPRESENTATIVE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
SUPERSEDES A670727

TX

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	TIME 4	CALL SIGN 6	ANT. DIMENSIONS 24
T01	MONT	EAGLEHEAD		4513XXN1108XXW			010	3		09GCOLLINEAR 09970MC015T

RECEIVER

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	RSN 3	AREA 3	CALL SIGN 6	ANT. DIMENSIONS 24
R01	MONT	BOZEMAN		4541XXN11102XXW			180				10GCORNREFLCTR05800MC056T
R02	MONT	TAYLORPK		4501XXN1112TXXW			035				09GCOLLINEAR 08500MC015T

LINE LABEL	CIRCUIT REMARKS 40
C01	*MRL,XXXXX,SCS218
C02	*DOC,16712678
C03	*AGN,REPEATER RECEIVES 169.450

LINE LABEL	SUPPLEMENTARY DETAILS
S01	ROUTINE. Update. Hydro Committee letter dated April 22, 1970.

CERTIFICATION: THIS IS TO CERTIFY THAT THERE IS AN IMMEDIATE OR EARLY NEED FOR THE REQUESTED ASSIGNMENT, THAT THE FREQUENCIES NOW AUTHORIZED FOR USE BY THIS AGENCY HAVE BEEN EXAMINED, EXISTING AUTHORIZATIONS DO NOT MEET THIS NEED, AND THE ADDITIONAL AUTHORIZATION REQUESTED OR ITS EQUIVALENT IS ESSENTIAL TO MEET THE AGENCY'S REQUIREMENTS SATISFACTORILY

SIGNED: Virgil M. ... Alt.
REPRESENTATIVE, FREQUENCY ASSIGNMENT SUBCOMMITTEE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

FORM OTP 80A JAN 70 (NEW OR NOTIFICATION)

Figure 9-2.--Radio frequency and station authorization--Continued.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
Washington, D. C. 20504

APPLICATION FOR FREQUENCY ASSIGNMENT ACTION

RECORD MRK	AGENCY SERIAL NO. 10	DATE 6
	A 701341	700731

LINE LABEL	LIST FREQUENCY 11	LIST ASSIGN. NO. 10
A01		

LINE LABEL	TYPE OF ACTION	CLASSIFICATION	FREQUENCY 11	AGENCY BUREAU 4	NET CONTROL 5	RELATED ACTION 6	ASSIGN. TYPE	JUSTIFICATION 5	JOINT APPLCTN BUREAU 4	TRUNK 6	EXP. DATE 4
F01	[illegible]		M171.075						S1		

LINE LABEL	STATION CLASS 4	EMISSION 7	POWER 9	NOTES 4
E01	[illegible]	16F2	0.005	
E02	[illegible]	16F3	0.005	

FOR AGENCY USE ONLY

DEPARTMENT OF AGRICULTURE

ASSIGNMENT APPROVED DATE 23 OCT 1970

DEPARTMENT OF AGRICULTURE REPRESENTATIVE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

SUPERSEDES

TX

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	TIME 4	CALL SIGN 6	ANT. DIMENSIONS 24
T01	MONT	LICK CR		4531XXN11057XXW			340	3		09GCOLLINEAR 0806XXX025T

RECEIVER

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	RSN 3	AREA 3	CALL SIGN 6	ANT. DIMENSIONS 24
R01	MONT	LICK CR		4530XXN11058XXW			020				09GCOLLINEAR 0686XXX015T
R02	MONT	[illegible]		4524XXN11057XXW			005				09GCOLLINEAR 081XXXX015T
R03	MONT	BOZEMAN		4541XXN11102XXW			180				10GCIRREFLCTR0480XXX056T

LINE LABEL	CIRCUIT REMARKS 40
C01	*HM,XXXX,SCS218
C02	*DCC,J079099
C03	*AGN,REPEATER RECEIVES 169.450

LINE LABEL	SUPPLEMENTARY DETAILS
S01	[illegible]. Update. Hydro Committee letter dated April 22, 1970.

CERTIFICATION: THIS IS TO CERTIFY THAT THERE IS AN IMMEDIATE OR EARLY NEED FOR THE REQUESTED ASSIGNMENT, THAT THE FREQUENCIES NOW AUTHORIZED FOR USE BY THIS AGENCY HAVE BEEN EXAMINED, EXISTING AUTHORIZATIONS DO NOT MEET THIS NEED, AND THE ADDITIONAL AUTHORIZATION REQUESTED OR ITS EQUIVALENT IS ESSENTIAL TO MEET THE AGENCY'S REQUIREMENTS SATISFACTORILY

SIGNED: [signature]
Alt.
REPRESENTATIVE, FREQUENCY ASSIGNMENT SUBCOMMITTEE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

FORM OEP 88A · JAN 70 (NEW OR NOTIFICATION)

Figure 9-2.--Radio frequency and station authorization--Continued.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
Washington, D. C. 20504

APPLICATION FOR FREQUENCY ASSIGNMENT ACTION

RECORD MARK	AGENCY SERIAL NO. 10	DATE 6
	A 701340	700731

LINE LABEL	LIST FREQUENCY 11	LIST ASSIGN. NO. 10
A01		

LINE LABEL	TYPE OF ACTION	CLASSIFICATION	FREQUENCY 11	AGENCY BUREAU 4	NET CONTROL 5	RELATED ACTION 6	ASSIGN. TYPE	JUSTIFICATION 5	JOINT APPLCTN BUREAU 4	TRUNK 6	EXP. DATE 4
F01	[illegible]		M169.45						S1		

LINE LABEL	STATION CLASS 4	EMISSION 7	POWER 9	NOTES 4
E01	[illegible]	16F2	0.005	
E02	FX	16F3	0.005	

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DEPARTMENT OF AGRICULTURE

ASSIGNMENT APPROVED DATE 23 OCT 1970

DEPARTMENT OF AGRICULTURE REPRESENTATIVE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

SUPERSEDES A670728

	LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7	ANTENNA LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	TIME 4	CALL SIGN 6	ANT. DIMENSIONS 24
TX	T01	MONT	TAILORPK		4501XX[illegible]	11127X[illegible]			035	3		09GCOLL[illegible]R 085[illegible]0015T

	LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7	ANTENNA LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	RSN 3	AREA 3	CALL SIGN 6	ANT. DIMENSIONS 24
RECEIVER	R01	MONT	EAGLE[illegible]		4513XX[illegible]	11108X[illegible]			010				09GCOLL[illegible]R 0997[illegible]056T

LINE LABEL	CIRCUIT REMARKS 40
C01	*[illegible],[illegible],SCS218
C02	*[illegible],R
C03	*DCC,I67A2679

LINE LABEL	SUPPLEMENTARY DETAILS
S01	[illegible]. Update. Hydro Committee letter dated April 22, 1970.

CERTIFICATION: THIS IS TO CERTIFY THAT THERE IS AN IMMEDIATE OR EARLY NEED FOR THE REQUESTED ASSIGNMENT, THAT THE FREQUENCIES NOW AUTHORIZED FOR USE BY THIS AGENCY [illegible] BEEN EXAMINED, EXISTING AUTHORIZATIONS DO NOT MEET THIS NEED, AND THE [illegible] TIONAL AUTHORIZATION REQUESTED OR ITS EQUIVALENT IS ESSENTIAL TO MEET THE AGENCY'S REQUIREMENTS SATISFACTORILY

SIGNED: [signature]
Alt. REPRESENTATIVE, FREQUENCY ASSIGNMENT SUBCOMMITTEE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

FORM OEP 88A JAN 70 (NEW OR NOTIFICATION)

Figure 9-2.--Radio frequency and station authorization--Continued.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
Washington, D. C. 20504
APPLICATION FOR FREQUENCY ASSIGNMENT ACTION

RECORD MARK	AGENCY SERIAL NO. 10	DATE 6
	A 701339	700731

LINE LABEL	LIST FREQUENCY 11	LIST ASSIGN. NO. 10
A01		

LINE LABEL	TYPE OF ACTION / CLASSIFICATION	FREQUENCY 11	AGENCY/BUREAU 4	NET CONTROL 5	RELATED ACTION 6	ASSIGN. TYPE	JUSTIFICATION 5	JOINT APPLCTN BUREAU 4	TRUNK 6	EXP. DATE 4
F01	NE	M169.45						S1		

LINE LABEL	STATION CLASS 4	EMISSION 7	POWER 9	NOTES 4
E01	FXH	16F2	0.005	
E02	FX	16F3	0.005	

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DEPARTMENT OF AGRICULTURE
ASSIGNMENT APPROVED DATE 23 OCT 1970
DEPARTMENT OF AGRICULTURE REPRESENTATIVE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
SUPERSEDES____________

TX

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	TIME 4	CALL SIGN 6	ANT. DIMENSIONS 24
T01	MONT	LICK CR		4530XXN11058XXW			020	3		09GCOLLINEAR 06860HD015E

RECEIVER

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	RSN 3	AREA 3	CALL SIGN 6	ANT. DIMENSIONS 24
R01	MONT	LICK CR		4531XXN11057XXW			340				09GCOLLINEAR 08060HD025E

LINE LABEL	CIRCUIT REMARKS 40
C01	*TRM,XXXXX,SCS218
C02	*REP,R
C03	*DOC,1079097

LINE LABEL	SUPPLEMENTARY DETAILS
S01	ROUNDUP. Update. Name changed from Repeater Site. Hydro Committee letter dated April 22, 1970.

CERTIFICATION: THIS IS TO CERTIFY THAT THERE IS AN IMMEDIATE OR EARLY NEED FOR THE REQUESTED ASSIGNMENT, THAT THE FREQUENCIES NOW AUTHORIZED FOR USE BY THIS AGEN[illegible]VE BEEN EXAMINED, EXISTING AUTHORIZATIONS DO NOT MEET THIS NEED, AND T[illegible]DI-TIONAL AUTHORIZATION REQUESTED OR ITS EQUIVALENT IS ESSENTIAL TO MEET THE AGENCY'S REQUIREMENTS SATISFACTORILY

SIGNED: Alt. REPRESENTATIVE, FREQUENCY ASSIGNMENT SUBCOMMITTEE INTERDEPARTMENT RADIO ADVISORY COMMITTEE

FORM OEP 88A · JAN 70 (NEW OR NOTIFICATION)

Figure 9-2.--Radio frequency and station authorization--Continued.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF THE DIRECTOR OF TELECOMMUNICATIONS MANAGEMENT
INTERDEPARTMENT RADIO ADVISORY COMMITTEE
Washington, D. C. 20504

APPLICATION FOR FREQUENCY ASSIGNMENT ACTION

AGENCY SERIAL NO. 10	DATE 6
A 701338	700731

LINE LABEL	LIST FREQUENCY 11	LIST ASSIGN. NO. 10
A01		

LINE LABEL	TYPE OF ACTION / CLASSIFICATION	FREQUENCY 11	AGENCY/BUREAU 4	NET CONTROL 5	RELATED ACTION 6	ASSIGN. TYPE	JUSTIFICATION 5	JOINT APPLCTN BUREAU 4	TRUNK 6	EXP. DATE 4
F01	MU	1169.45						S1		

LINE LABEL	STATION CLASS 4	EMISSION 7	POWER 9	NOTES 4
E01	FXH	16F2	0.005	
E02	FX	16F3	0.005	

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DEPARTMENT OF AGRICULTURE

ASSIGNMENT APPROVED DATE 23 OCT 1970

DEPARTMENT OF AGRICULTURE REPRESENTATIVE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

SUPERSEDES

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	TIME 4		CALL SIGN 6	ANT. DIMENSIONS 24
TX T01	MONT	SHWRFLLS		4524XXX1057XXW			005	3			09GCOLLINEAR 08100N0015T

LINE LABEL	ST/CT 4	ANTENNA LOCATION 8	CONTROL 8	ANTENNA LAT. 7 LONG. 8	CNT 3	ANT. NAME 3	ANT. ORIENT. 3	RSN 3	AREA 3	CALL SIGN 6	ANT. DIMENSIONS 24
RECEIVER R01	MONT	LECK CR		4531XXX1057XXW			340				09GCOLLINEAR 08960N0025T

LINE LABEL	CIRCUIT REMARKS 40
C01	*IRM,XXXXX,SCS218
C02	*REF,R
C03	*DOC,I079095

LINE LABEL	SUPPLEMENTARY DETAILS
S01	ROUTINE. Update. Name changed from Devil Slide. Hydro Committee letter dated April 22, 1970.

CERTIFICATION: THIS IS TO CERTIFY THAT THERE IS AN IMMEDIATE OR EARLY NEED FOR THE REQUESTED ASSIGNMENT, THAT THE FREQUENCIES NOW AUTHORIZED FOR USE BY THIS AGENCY HAVE BEEN EXAMINED, EXISTING AUTHORIZATIONS DO NOT MEET THIS NEED, AND THE ADDITIONAL AUTHORIZATION REQUESTED OR ITS EQUIVALENT IS ESSENTIAL TO MEET THE AGENCY'S REQUIREMENTS SATISFACTORILY

SIGNED: [signature]
Alt.
REPRESENTATIVE, FREQUENCY ASSIGNMENT SUBCOMMITTEE
INTERDEPARTMENT RADIO ADVISORY COMMITTEE

FORM OCP 88A JAN 70 (NEW OR NOTIFICATION)

Figure 9-2.--Radio frequency and station authorization--Continued.

BY vmw DATE 4/70 SUBJECT FREQUENCY USAGE SHEET NO. 1 OF 1

CHKD. BY DATE SOIL CONSERVATION SERVICE JOB NO.

BOZEMAN, MONTANA SYSTEM

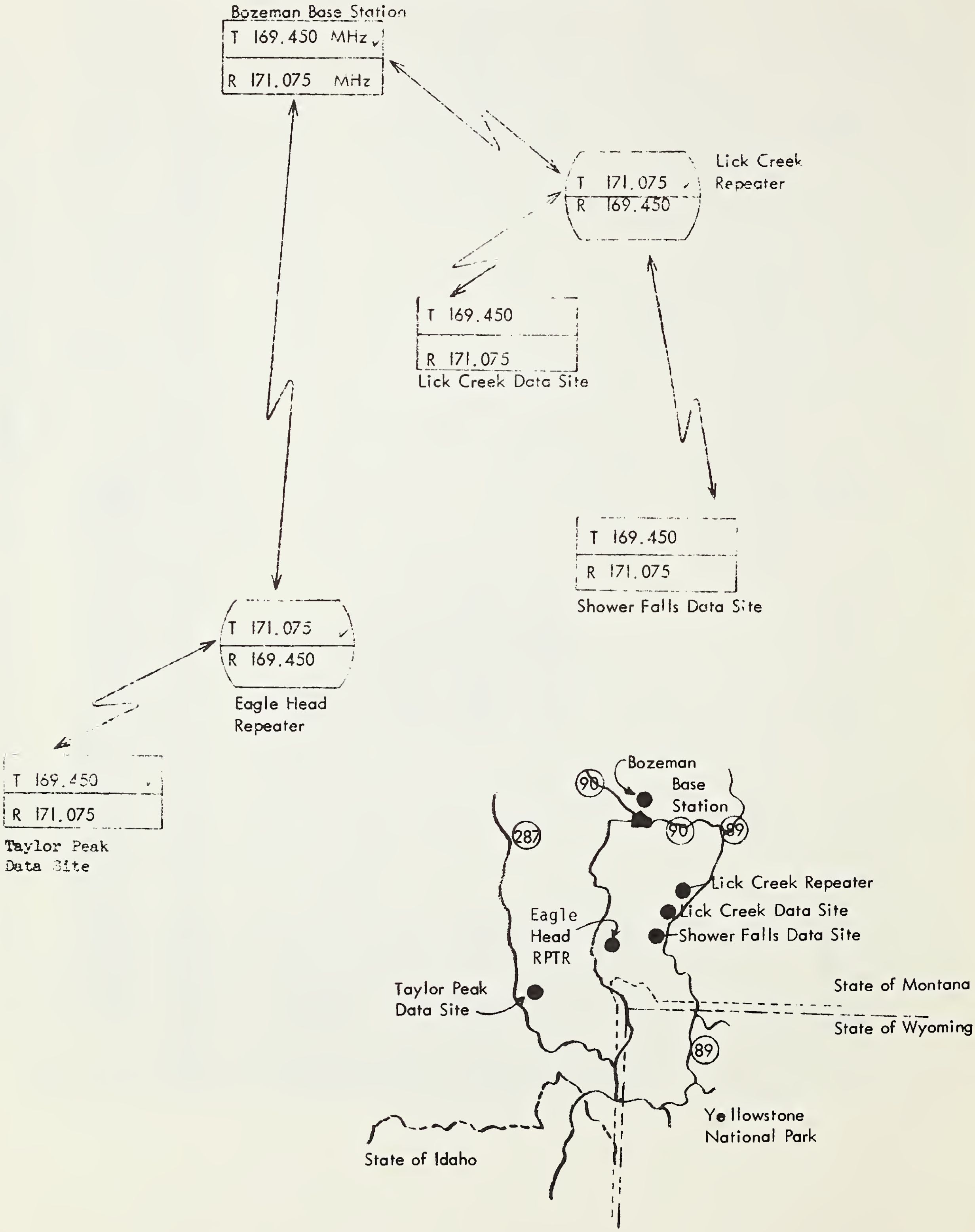

Figure 9-2.--Radio frequency and station authorization--Continued

Type of modulation or emission	Type of Transmission	Symbol
Amplitude	With no modulation	A0
	Telegraphy without the use of a modulating audio frequency (by on-off keying)	A1
	Telegraphy by the on-off keying of an amplitude-modulating audio frequency or audio frequencies, or by the on-off keying of the modulated emission (special case: an unkeyed emission amplitude modulated)	A2
	Telephony	
	Double sideband, full carrier	A3
	Single sideband, reduced carrier	A3A
	Single sideband, suppressed carrier	A3J
	Two independent sidebands, reduced carrier	A3B
	Facsimile (with modulation of main carrier either directly or by a frequency-modulated subcarrier)	A4
	Single sideband, reduced carrier	A4A
	Television	A5
	Vestigial sideband	A5C
	Multichannel voice-frequency telegraphy	A7
	Single sideband, reduced carrier	A7A
	Cases not covered by the above, such as a combination of telephony and telegraphy	A9
	Two independent sidebands	A9B
Frequency (or phase)	With no modulation	F0
	Telegraphy by frequency-shift keying without the use of a modulating audio frequency; one of two frequencies being emitted at any instant	F1
	Telegraphy by the on-off keying of a frequency-modulating audio frequency or by the on-off keying of a frequency-modulated emission (special case: an unkeyed emission frequency modulated)	F2
	Telephony	F3
	Facsimile by direct frequency modulation of the carrier	F4
	Television	F5
	Four-frequency diplex telegraphy	F6
	Cases not covered by the above in which the main carrier is frequency modulated	F9
Pulse	A pulsed carrier without any modulation intended to carry information, for example, radar	P0
	Telegraphy by the on-off keying of a pulsed carrier without the use of a modulating audio frequency	P1D
	Telegraphy by the on-off keying of a modulating audio frequency or audio frequencies, or by the on-off keying of a modulated pulsed carrier (special case: an unkeyed modulated pulsed carrier)	P2
	Audio frequency or frequencies modulating the amplitude of the pulses	P2D
	Audio frequency or frequencies modulating the width (or duration) of the pulses	P2E
	Audio frequency or frequencies modulating the phase (or position) of the pulses	P2F
	Telephony	P3
	Amplitude modulated pulses	P3D
	Width (or duration) modulated pulses	P3E
	Phase (or position) modulated pulses	P3F
	Code modulated pulses (after sampling and quantization)	P3G
	Cases not covered by the above in which the main carrier is pulse modulated	P9

Source: Howard W. Sams & Co., Inc. Reference Data for Radio Engineers. Fifth Edition.

Figure 9-3.--Types of radio emissions--FCC symbols.

The most commonly used symbols for classes of stations--Continued

MO Mobile Station. A station in the mobile service intended to be used while in motion or during halts at unspecified points

MR Radiolocation Mobile Station. A station in the radiolocation service intended to be used while in motion or during halts at unspecified points

MS Ship Station. A mobile station in the maritime mobile service located on board a vessel (ship), other than a survival craft that is not permanently moored

XR Experimental Research Station. An experimental station used in basic studies concerning scientific investigation looking toward the improvement of the art of radio communications

XD Experimental Developmental Station. An experimental station used for evaluation or testing of electronics equipment or systems in a design or development stage

XT Experimental Testing Station. An experimental station used for evaluation or testing of electronics equipment or systems, including site selection and transmission path surveys that have been developed for operational use

Purchase of Equipment

The purchase of radio equipment requires a station and frequency authorization. Normal types of radio equipment for snow surveying and water supply forecasting are: (1) low-power hand sets for voice communication; (2) mobile and base station voice communication sets; and (3) data collection devices and associated encoding and transmitting equipment, repeater stations, base station, and readout and printing or recording equipment.

SCS has authority to operate low-power portable equipment (Type 1) with power output of up to 1 watt. The frequency assignment for this use is 27.575 mc/s, 6A3 type of emission and mobile class of station covered under SCS Frequency Authorization No. 23a, May 14, 1963. This type of equipment is available under General Services Administration Federal Supply Schedule Contracts.

Voice communication equipment (Type 2) using mobile, repeater, and base station equipment generally is obtained from commercial sources.

The use of equipment for the collection and transmission of basic data (Type 3) usually involves:

1. The purchase of commercially available components.
2. A negotiated contract for procuring and assembling equipment for a given purpose.
3. An agreement with a university or other development group for designing, constructing, and testing equipment for specific purposes.

Radio equipment may not be purchased without prior approval of the Washington office. (see Administrative Services Handbook, 106, Group 58). Such approval is required because of the necessity for station and frequency clearance and adherence to IRAC rules and regulations and specifications. Forest Service specifications are used when applicable.

Installation

Hand or portable radio communication sets are self-contained and, therefore, require no installation. This type of equipment, as set forth in the frequency authorization, can be used only in mobile operation. Regular voice communication equipment using mobile, repeater, and base stations must be installed by qualified radio technicians. This work may be done by private individuals, or by local companies having the technical ability and FCC license, or by agreement with federal or state agencies having qualified radio technicians.

The installation of equipment for collecting and transmitting basic data includes rights-of-way, right of ingress and egress, site preparation, shelter houses, transportation of equipment, tools and materials, and the location and connection of components. SCS generally obtains rights-of-way and rights of ingress and egress and handles other matters. Contracts or agreements can be executed to cover other items in the installation.

Operation

Only authorized personnel of SCS should be permitted to operate radio communication equipment. The Code of Federal Regulations, Title 47 - Telecommunication contains operating procedures for voice communication and prohibitions on unauthorized use. These regulations, in general, prescribe that unauthorized persons may not operate equipment, that use must be for official business and for the purposes indicated in the authorization, that stations must be properly identified at intervals and at the beginning and end of transmissions, that no profane or obscene language may be used, and that no false distress or emergency calls may be issued. If the frequency is shared, listen before transmitting to be sure no one is using it.

The operation of telemetry equipment is automatic; information is received by interrogation. Tone or coded signals provide the information that is transmitted. Operation of this equipment should be in accordance with the station and frequency authorization.

Training of Snow Surveyors

Training Requirements

The accuracy and reliability of snow survey measurements depend on the integrity and training of the individual snow surveyor. Although the measurement of snow and other variables is not a complex procedure when operations go well, the snow surveyor must know how such measurements

462-302 O - 72 - 14

are obtained. He must also understand what to do when situations are unusual. Of equal importance is the safety of the snow surveyor.

Kinds of Training

Experience shows that regardless of the skill of the individual in other fields, the best snow surveyors are those who are trained specifically in snow surveying. Most of the credit for the outstanding safety record in snow surveying can be given to the well-trained surveyors. In addition to snow survey training conducted by regional or westwide schools and by schools within one state, there is on-the-job training.

Westwide Training Schools
A Westwide training school is held as needed, usually once every 2 years for a period of 1 week with about 100 trainees in each school. Instructors are experts in their field. In addition to training those in attendance, the westwide school establishes training standards and provides instructors for state and local schools and for individual training. This training also helps to set standards of operation that make data comparable from state to state and among snow survey parties. The westwide schools are designed to train snow surveyors or potential snow surveyors in those skills needed to perform fieldwork; they also present information on how to use data collected in the field.

Selecting a Site.--Sites for schools should be selected a year or two in advance so that all arrangements can be made with the specific site in mind. Physical features that are necessary for a site are:

1. Accessibility by automobile. The area should be served by commercial air and ground transportation. Most of the students as well as instructors need a considerable amount of equipment at the schools, and skis, snowshoes, bedrolls, and a variety of heavy clothing are difficult to transport. The greater the distance from the road or from a transportation center, the more complex transport problems become.
2. Enough housing to accommodate all the instructors and students. Quarters should be clean, comfortable, and with enough space for a large amount of personal clothing and equipment. Storage as well as repair facilities should be provided for skis, snowshoes, bedrolls, and miscellaneous equipment. Lodging, meeting, and eating facilities should be close together. Arrangements for quarters should also include food. Meals should be wholesome and adequate, and identical for all. At least four meeting rooms for 25 people each should be available for classes that are held simultaneously, and a general meeting room for 100 people should be provided.
3. Enough snowfall (3 feet or more) for fieldwork in survival techniques, skiing, and cross-country travel. Working areas should be protected from wind by timber. Field areas should be adequate in size and convenient to the housing area. Open areas are needed for snow sampling, and wooded areas are better for survival training and cross-country travel.
4. A good beginner's ski slope within walking distance of the housing area.

Usually not all desirable site conditions can be met, but any major deficiencies indicate the need to select another site.

Subjects Taught.--In westwide schools trainees are taught a variety of skills to make them proficient in snow surveying and in obtaining related data. A major exception is operation and emergency repair of oversnow machines, which is taught best on the job. Practice for repairs that can be done in the field is best conducted indoors. The following are major subjects:

1. Snow and Soil Moisture Sampling and Measurement of Precipitation Gages.--This subject is covered by a general discussion of technique to a class indoors, demonstration of technique to the class in the sampling area, and supervision of small groups actually doing the work. A critique should be held at the end of the instruction to check work and review difficulties. The exact method of instruction depends on weather conditions, the instructor's approach, and sampling problems in the area.

2. Survival.--Classroom instruction should cover general principles of how to survive in the snow. The demonstration and application must be taught in the snow. Instructors have various types of shelters constructed for demonstration purposes. Trainees are required to construct their own shelters and to stay in them one night. Instructors and those in charge of the school must check that survival shelter and equipment are adequate. Persons experienced in survival techniques should stay with the trainees overnight in the snow. If a severe storm or temperatures below -20° F. are expected during the night, the overnight stay in the snow should be postponed or canceled. Arrangements for sleeping bags, hand tools, and incidental equipment are made in advance.

3. Cross-country Travel.--A limited amount of instruction and demonstration is required on such subjects as use of climbers, making emergency climbers, adjustment of skis and snowshoes, route selection, and proper fitting of boots and clothing. The cross-country trip of 4 to 6 miles should include varying terrain with steep slopes, side slopes, and timbered areas as well as open and level areas.

4. Ski Instruction.--Each trainee should learn to ski as an alternative to snowshoe travel, but time is not available for training professional downhill skiers. Professional ski instructors should be used to teach classes of no more than 10 to 12 persons. All persons are assumed to be beginners until instructors have a chance to evaluate their skills. Classes may be divided then by skill of individuals. A SCS snow survey supervisor coordinates the training and prepares the course outline.

5. Care of Equipment.--Instruction includes care and maintenance of skis, snowshoes, special clothing, sampling equipment, soil moisture meters, and other equipment. Each snow surveyor should be familiar enough with the construction of the equipment so he can recognize if it is defective.

6. Winter Safety and Health.--This class is primarily about first aid; the instructor emphasizes situations that may occur while traveling in cold weather and snow.

7. Observation of Aerial Snow Depth Markers.--While this observation cannot be practiced in school, instructors discuss how air observations are made, safety measures in obtaining them, and the use of such data as a substitute for ground measurements.

These subjects give a snow surveyor the basic knowledge and skills he must have to do his job. In addition, to help the snow surveyor understand the importance of his work, and how it relates to water supply forecasting, brief presentations are given on the following subjects:

1. Theory of water supply forecasting.
2. Use of related data, such as precipitation, wind, radiation, groundwater, and streamflow.
3. Interpretation of water supply outlook reports.
4. Forecast accuracy.
5. Application of water supply forecasts to water operations.
6. News releases on snow surveys and water supply outlook.

Instructors.--Westwide schools bring together experienced instructors in the various subjects. The large number of trainees justify making a substantial effort in planning the instruction and in providing training aids such as charts, slides, models, movies, and exhibits.

Although much of the instruction is presented by SCS snow survey supervisors, instruction in skiing, survival techniques, and first aid is provided by persons particularly skilled in those subjects.

State and Local Schools

These schools, which offer 2 or 3 days of instruction, are designed to reach snow surveyors who are unable to attend the westwide schools. Subjects taught at the westwide schools cover many general areas, but state and local schools emphasize the problems most likely to be found in the state or area. Methods of data collection are important everywhere, but varying emphasis can be placed on such subjects as survival training, cross-country travel, and skiing.

On-the-Job Training

Snow surveyors who are temporary or occasional members of a party receive much of their training directly from an experienced snow surveyor. The man in charge of a trip should have had formal training; no difficult trips should be attempted by untrained personnel. If special types of equipment must be observed or used, individual instruction is best. The major type of equipment requiring such instruction is the oversnow machine.

Cooperative Relations and Agreements

Cooperative Relations

It is SCS policy to cooperate to the fullest extent possible with federal, state, and local agencies in conducting snow surveys.

The following agencies and groups assist in collecting data used in water supply forecasting:

Soil and Water Conservation Districts

SCS provides technical assistance to farmers, ranchers, and others cooperating with soil and water conservation districts. Forecast information prepared by the snow survey supervisor is provided to work unit conservationists, water managers, irrigation companies, and others to assist them in planning and using water more efficiently. Forecast meetings sponsored by local groups or agencies provide another method of presenting pertinent water supply information to those interested and in need of it.

State Agencies

SCS gets a considerable amount of cooperation and participation in snow surveys from state agencies. Participation, provided primarily by the state agency having responsibility for water rights and resources, agricultural experiment stations, and fish and wildlife agencies, requires grants of funds, services, facilities, and materials. Recognition should be given to these agencies in formal SCS reports and publications.

Local Agencies and Groups

Irrigation districts, power companies, municipalities, private corporations, and local communities need forecast data, and they cooperate by providing funds, services, facilities, and supplies. Cooperation and participation of these agencies and groups are encouraged and in some instances specialized equipment such as sampling sets may be lent to such groups measuring snow courses. Work by the cooperators should be with the knowledge and under the direction of snow survey supervisors, and the quality of work must meet minimum SCS standards.

Federal Agencies

Forest Service.--Many snow courses are located in national forests. Many of these are measured by Forest Service personnel. Establishment or modification of snow courses or data collection installations in the national forests requires special site authorization that generally is issued by the local forest supervisor.

Measurement of snow courses and other tasks performed by Forest Service personnel are scheduled annually through agreements with the regional offices of the Forest Service and by informal arrangement with local forest supervisors.

Every precaution should be taken to protect snow courses and other installations from activities that may impair their usefulness, such as logging and road building. The snow survey supervisor should make certain that maps and other location information are provided to the forest supervisor and that agreement is reached to protect these courses and installations. This information should be kept current.

Bureau of Reclamation, Army Corps of Engineers, and Bonneville Power Administration.--Basic hydrologic data and information are provided to the Bureau of Reclamation, Army Corps of Engineers, and Bonneville Power Administration on request. Specific requests by these agencies for data that are not collected or obtained as a part of the normal operations are considered on a case-by-case basis. Generally, these agencies are expected to reimburse SCS for the cost of these special services or installations.

U.S. Geological Survey (USGS).--SCS obtains most of its streamflow data for forecast purposes from the U.S. Geological Survey. Much of this information is needed in advance of the normal publication date. Therefore, the snow survey supervisor should establish a working arrangement with USGS representatives for the exchange of data as needed. Credit should be given USGS in formal SCS reports and publications for any information they supply.

USGS measures a number of snow courses in the West--most of them are in Washington and Montana. This information is available to SCS for inclusion as part of the network data.

Bureau of the Budget Circular No. A-67, August 28, 1964, sets up policy on coordination of federal activities in obtaining certain water data.

National Oceanic and Atmospheric Administration (NOAA).--NOAA collects certain precipitation data that are useful in preparing water supply forecasts. Also, SCS collects high-elevation snow and other data that help in appraising flood-flow potentials and certain volume and residual flows. Normally, working arrangements at local levels insure a free flow of data between agencies. Bureau of the Budget Circular No. A-62, November 13, 1963, contains certain policies and procedures for the coordination of federal meteorological services.

Bureau of Indian Affairs.--SCS provides snow survey data and water supply forecast information to the Bureau of Indian Affairs for its use in the administration of Indian lands. The Bureau of Indian Affairs cooperates in this activity by supplying funds, services, equipment, and materials. The installation, operation, and maintenance of snow courses and equipment for data collection on Indian lands requires mutually agreeable arrangements about funds, services, and annual schedules.

National Park Service.--Some snow courses are in the national parks. The National Park Service cooperates in snow surveys by measuring snow courses and supplying other services. The snow survey supervisor should maintain working arrangements with the individual national parks and supply them necessary equipment, annual schedules, and instructions.

California and British Columbia

SCS has no formalized cooperative agreement covering snow surveys with any state agency in California, other than traditional understanding whereby SCS recognizes the Department of Water Resources as having responsibility for snow surveys and water supply forecasts in that state. Snow surveys on the east slope of the Sierras in California and on streams that flow into Nevada are conducted by the SCS Nevada state office.

SCS seeks the continued cooperation of the Department of Water Resources in California on the subject of Westwide Water Supply Outlook as well as from the Water Resources Service of the Department of Lands, Forests, and Water Resources, which is responsible for snow surveys in British Columbia. Working arrangements provide for exchange of data between SCS and these agencies.

Cooperative Agreements

The cooperative nature of this work involves transfer of funds, reimbursements, acceptance of gratuitous equipment and services, agreements, and other arrangements. In developing these cooperative arrangements, the procedures and policies of the Administrative Services and the Budget and Finance Divisions are followed.

Assistance may be provided by WSFU in developing agreements if more than one state is involved. The technical and operations information necessary to prepare agreements is supplied by snow survey employees.

Snow survey activities require the following agreements:

1. Permits for locating and operating data collection sites in national forests and parks and on other federal land.
2. Permits or permission to place data collection sites on private and state land.
3. Informal agreements for services--generally letters or memorandums covering measurement of snow courses and other data-gathering functions.
4. Formal signed agreements covering reimbursement or payment of funds for services such as data collection, development and installation of equipment, data processing, printing, exchange of data, and other joint activities.

The procedure for preparing letters of understanding and other kinds of agreements is given in the Administrative Services Handbook. The handbook also indicates the line officers having authority to sign agreements.

Program Evaluation

The snow survey and water supply forecasting program provides a service to both rural and urban people. Irrigation farmers represent a major group needing forecast information. Water management agencies or

organizations needing data for power generation, flood control, winter recreation, and improving fish and wildlife habitats also benefit.

The water supply forecasting program must consider the public needs, the costs, and the benefits. Thus, it is desirable to determine the benefits accruing to the activity and the beneficiaries. Such studies (1, 2, 3) provide a basis for justifying expenditure of funds and for determining the worth of this program in relationship to other work of SCS.

Determination of Benefits

An economic evaluation of this activity is made by comparing the costs and services expended with the monetary and other values received. The costs can be summarized by adding up funds expended by SCS, including those from other federal, state, and local agencies. The monetary worth of services and materials contributed is determined by assigning actual and estimated fair values.

The effects of snow survey and water supply forecasts range from direct monetary to esthetic values. Because of the intangible values, it is not possible to arrive at an exact dollar figure for the entire effort. It is possible, however, to determine the relative magnitude of benefits and associated costs by examining the uses made of basic data and forecasts by agricultural users, public agencies, industry, and other major groups, and then the relationship of this use to the total function.

Kinds of Benefits

Irrigation

The following is one type of model for estimating irrigation benefits derived from advance information on seasonal water supply. The premise here is that a farmer without water supply information will plant substantially the same acreage and crops each year. With information he will shift acreage and type of crops to realize the least loss or the greatest benefit.

Determine the total irrigated area within the state.

Determine the acreage irrigated totally or in part from surface water sources. Of this acreage, determine the amount affected by water supply forecasts.

Using sampling procedures, determine types of irrigation enterprises and the total acreage in each type.

Using representative sample areas of each type, determine the average size of farm, crops grown, farming procedures, fixed and variable costs, and gross and net returns to the farmer, assuming normal or average water supply. This establishes a base for comparing alternatives in those years in which the available water supply is considerably less or more than normal.

Example: Assume two identical farms of 200 acres each. Each farm irrigates 150 acres with a normal water supply.

Determine fixed costs consisting of taxes, insurance, water charges, fencing, ditch maintenance, and machinery amortization. In this example, these costs amount to $5,000 for each farm. From cost and return analysis and crop rotation used, the per acre weighted return over operating expenses is about $80 per acre for every acre fully irrigated on the farm. To determine the net farm income for the model having advance information on water supply forecast--first, calculate what percentage of the water supply is normal; second, multiply this percentage by 150 acres; third, multiply the product in the second step by $80; and fourth, subtract from this product $5,000 in farm fixed cost.

The farmer without water supply information will plant all the 150 acres and hope that he gets a normal supply. In a normal year the returns will be the same for both farms.

Figure 9-4 shows the net farm income or loss based on the percentage of normal water supply available on a 200-acre irrigated farm in southern Idaho with water rights for only 150 acres in a normal year. In this example, the weighted gross return less operating expenses is a minus $32.60 per acre for a 50-percent year when 150 acres were planted. Figures 9-5 and 9-6 give additional comparisons of income based on percentage of normal water supply.

A family of curves as shown in Figure 9-4 can be developed for each type of irrigation farming enterprise. By applying the percentage of water supply to particular watersheds and acreages, an annual benefit can be determined. An average annual amount can be computed by using a 10-year or longer record.

Tables 9-2 and 9-3 show economic benefits from using water supply forecasts based on an SCS study made in Boise, Idaho.

Table 9-2.--Savings in planting costs in two irrigated areas

Crop	Normal planting	1960 planting	Difference	Planting costs per acre	Dollar savings
	Acres	Acres	Acres	Dollars	Dollars
Alfalfa	12,140	12,140	--		
Dry beans	8,400	6,180	2,220	$21.80	$ 48,396
Grain	7,530	5,610	1,920	23.40	44,928
Potatoes	3,160	675	2,485	65.90	163,761
	31,230	24,605	6,625		$257,085

Note: The largest reduction in water-using requirements was in acreage of potatoes, which is also the crop requiring the highest investment cost for planting. The alfalfa acreage was not changed and served as a buffer crop. No water was available for late season irrigation. Full yield was not obtained, but the acreage remains unchanged.

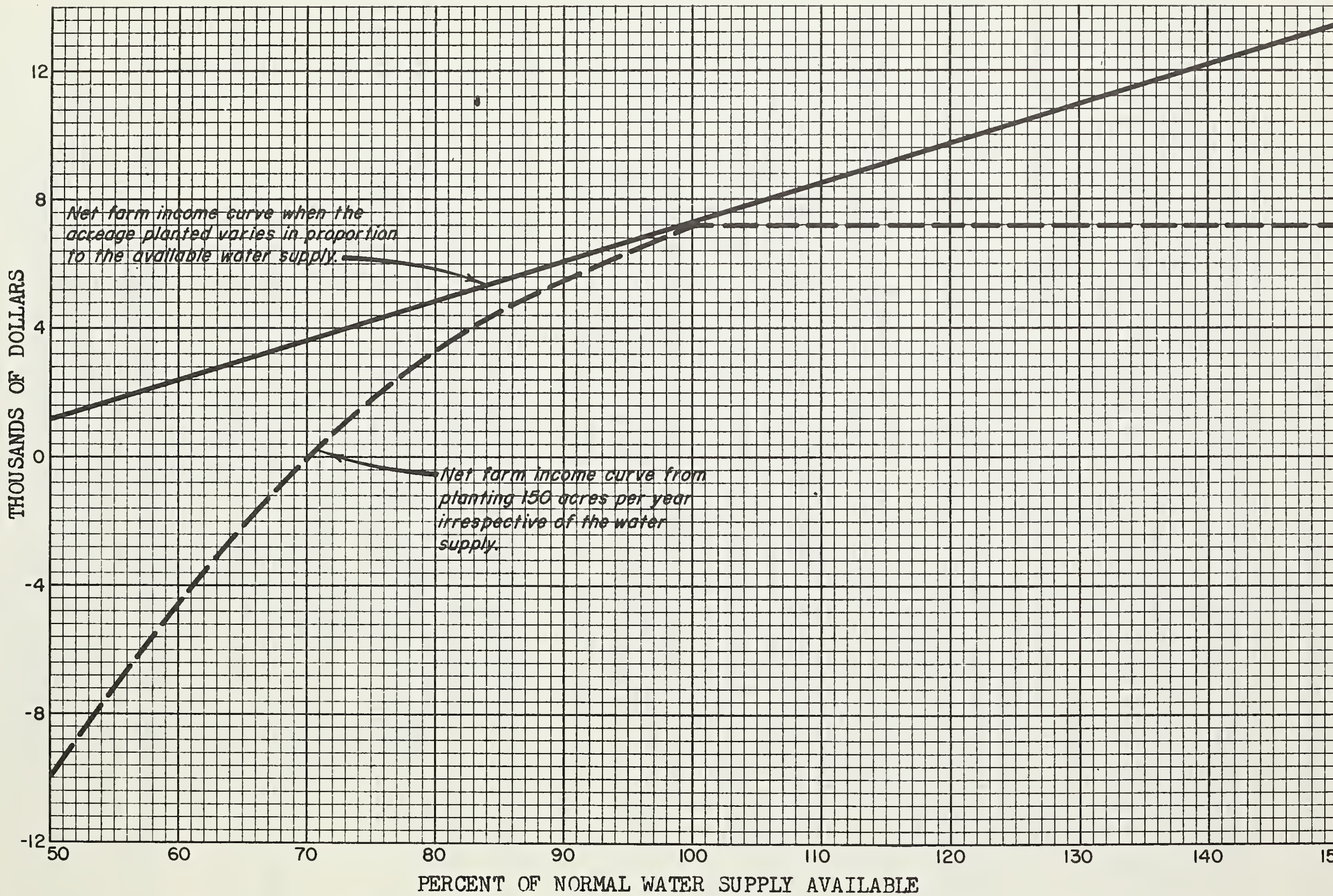

Figure 9-4.--Net farm income or loss with and without knowing the available water supply each year.

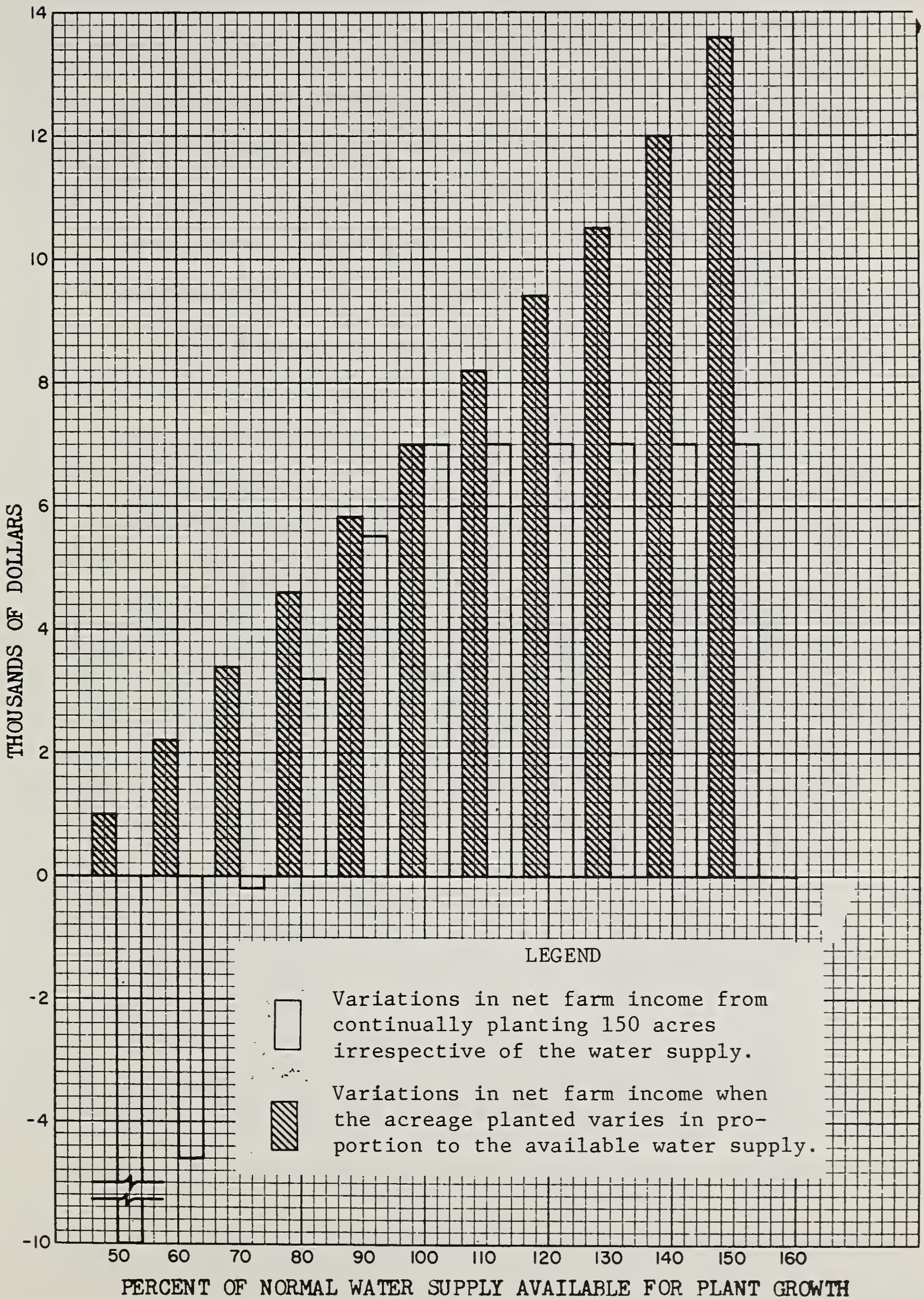

Figure 9-5.--Net farm income with and without knowing the available water supply from year to year.

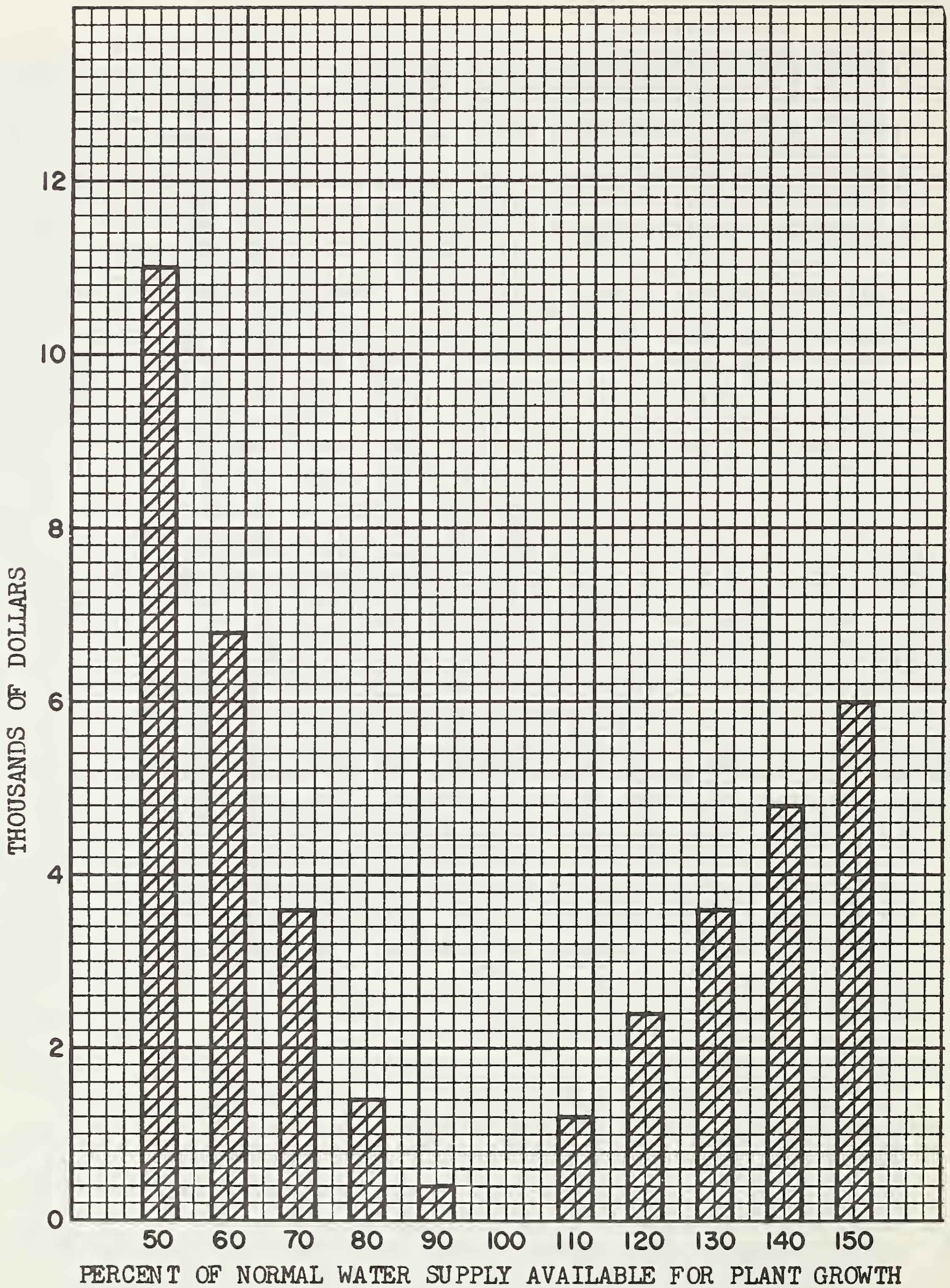

Figure 9-6.--Total value of knowing the year's water supply for different percentages from a normal water supply year.

Greater crop production results from an adequate water supply used on limited acreage than from a deficient water supply on normal acreage; no water in late season results in crop failure.

In addition to planting cost benefits, other benefits were obtained from savings in water not used for preirrigation but applied to other crops. (In these areas the practice was to apply from 4 to 12 inches of water before planting.)

Table 9-3.--Crop production using water not used for preplanting irrigation

Crop	Average yield	Net income	Cropping pattern	Weighted net income
			Percent	
Beans	20 sacks	$ 79.75	50	$39.88
Grain	60 bushels	39.40	45	17.72
Potatoes	200 sacks	130.00	5	6.50
Average weighted net income per acre				$64.10

Based on a savings of 0.33 feet on the 4,705 acres (grain not normally preirrigated) and 2.5 acre-feet as the average seasonal water requirement for adequately irrigated acreage--4,705 multiplied by 0.33 divided by 2.5--about 620 acres were irrigated from savings in preplanting use of irrigation water. Multiplying the average net income per acre of $64.10 by 620 acres gives a savings of $39,740. This savings of $39,740 added to the savings in planting costs of $257,085 gives a total savings of $296,825.

Flood Control

Basin water management agencies can estimate the flood damages prevented by controlling storage in flood-control reservoirs. The ability to manipulate storage facilities to accommodate flood volumes and reduce peak flows comes from knowledge of snow conditions, precipitation, stored volumes, stream hydrographs, and related factors. Above-normal snowfall in the mountains indicates excess flow and potential flooding.

Evaluation of the worth of the snow data depends on the weight given this factor and the action taken. For example, if the snow cover above a major reservoir is 180 percent of normal and the reservoir is full, action such as releasing water to provide storage for expected excessive flows is indicated. In this example, almost 100-percent weight is given to the snow cover conditions that produced this action. Thus, all damages prevented by storage regulation could be credited to the snow survey data. Usually the action taken results from considering several factors, of which water content of snow may be one; the relative weight of snow data to other parameters must be determined too. Multiplying this figure by the damages prevented gives some measure of the worth of the snow data.

Management of Irrigation Reservoir Storage

In management of the Colorado River water must be allotted between the upper and lower basins. Here, as for flood control, advance information on the seasonal volume of water that will reach main stream reservoirs permits efficient management of available storage. Again its worth is determined by the weight given to snow data in actions required for management operations. It is necessary to consider each reservoir individually and the extent to which snow survey data are used to obtain an estimate of worth.

Power Generation

An acre-foot of water in a reservoir at some given elevation generates a quantity of power that has certain value. It is necessary to release or store water according to fixed operating schedules as based on multiple-purpose requirements. Advance forecast information on probable streamflow permits regulating storage to realize the maximum power returns for available supply. Thus, evaluating the worth of forecast information is based on the action taken that otherwise would not have been taken without knowing the snow runoff potential. Each reservoir must be considered separately according to its operating procedure and the effect of snow survey information.

Development of Recreation and Fish and Wildlife, and Pollution Abatement

As a general rule, it is difficult to arrive at monetary benefits for this group of purposes. There may be a few situations where an estimate of monetary benefits can be obtained such as those from an increase in fish population due to flow regulation. Such an evaluation requires use of snow data or forecast information that result in a measurable output that can be evaluated.

Use of snow survey data and forecast information permits flow regulation, maintenance of lake or reservoir levels, seasonal distribution of water, and improved water quality. Such benefits may be tangible or intangible based on the particular lake, reservoir, or stream reach. Thus, the evaluation procedure is one of determining the particular use of data, the results, and a monetary or narrative evaluation.

Special Uses

Snow survey data provide valuable information for special uses. Examples are for selection and operation of winter sports areas, road location, designing structures (information on snow load), estimating volume flow at dam construction sites, basin and watershed planning, and municipal and industrial water supply studies. Many of these special uses produce tangible and monetary benefits that can be determined by standard economic procedures. There are also intangible but real benefits that are difficult to express in monetary terms. The evaluation procedure is to review each special use, determine what snow survey data were used, and, if possible, discover what results were achieved either in monetary or nonmonetary terms.

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